POWERPLANT

OVERVIEW

The PW1100G-JM turbofan engine powers the Airbus A320neo (New Engine Option) aircraft. It is an axial-flow, twin spool turbofan engine with an ultra-high bypass ratio, low speed gear-driven fan.

The engine includes core-mounted Angle and Main gearboxes, and is mounted on a pylon that extends below and forward of the wing leading edge.

Also known as the *power plant,* the engine supplies propulsive energy to the aircraft and provides electrical power and hydraulic pressure for aircraft systems.

In addition, it supplies pressurized air for the aircraft Environmental Control System (ECS) that includes cabin pressurization, heating, and cooling.

The power plant includes the basic engine with its control components, the nacelle, engine mounts, and Engine Build-up Units (EBU).

The engine is controlled by the Full Authority Digital Electronic Control (FADEC) system and is designed for safe and reliable operation. Proper ground run danger zones must be observed for the power plant, as well as steps for preservation and replacement.

Advantages of the PW1100G-JM Engine

Conventional gas turbine engines cannot perform as efficiently as the PW1100G-JM.

The low-pressure compressor and low-pressure turbine are restricted to less-than-optimal operating speeds so that fan speed can be maintained in a range most efficient for fan diameter.

The geared technology of the PW1100G-JM allows the fan and low-pressure rotor to operate at optimal, independent speeds for peak efficiency.

These improvements in performance reduce fuel consumption, air pollution, and noise. At the same time, operating costs and environmental impact are drastically reduced.

Safety Conditions

WARNING

BE CAREFUL WHEN YOU WORK ON THE ENGINE AFTER SHUTDOWN. THE ENGINE AND ENGINE OIL CAN STAY HOT FOR A LONG TIME. IF YOU DO NOT OBEY THIS WARNING, INJURY CAN OCCUR.

REFER TO THE MSDS FOR ALL MATERIAL USED AND THE MANUFACTURER'S SAFETY INSTRUCTIONS FOR ALL EQUIPMENT USED.

IF YOU DO NOT OBEY THIS WARNING, INJURY CAN OCCUR.

Aircraft and Engine Specifications		PW1100G Designation
Thrust		24,000 – 35,000 lbs
Bypass ratio		12:1
Engine inlet diameter	Overall nacelle	102 in. (259 cm)
	Fan blade tip	81 in. (205.7 cm)
Engine weight of demountable power plant		7457 lb (3382 kg)
Aircraft models		A319, A320, A321
Passenger capacity		124 – 235

Sample Naming Convention: A320 Family	
PW	Pratt & Whitney
1	Engine model 1000
1	Airbus airframe
33	Thrust in lbs x 1,000
G	Geared Turbo Fan (GTF)
J	Japanese Aero Engines Corporation (JAEC)
M	Motoren-und-Turbinen-Union Aero Engines (MTU)

NEO SPECIFICATIONS

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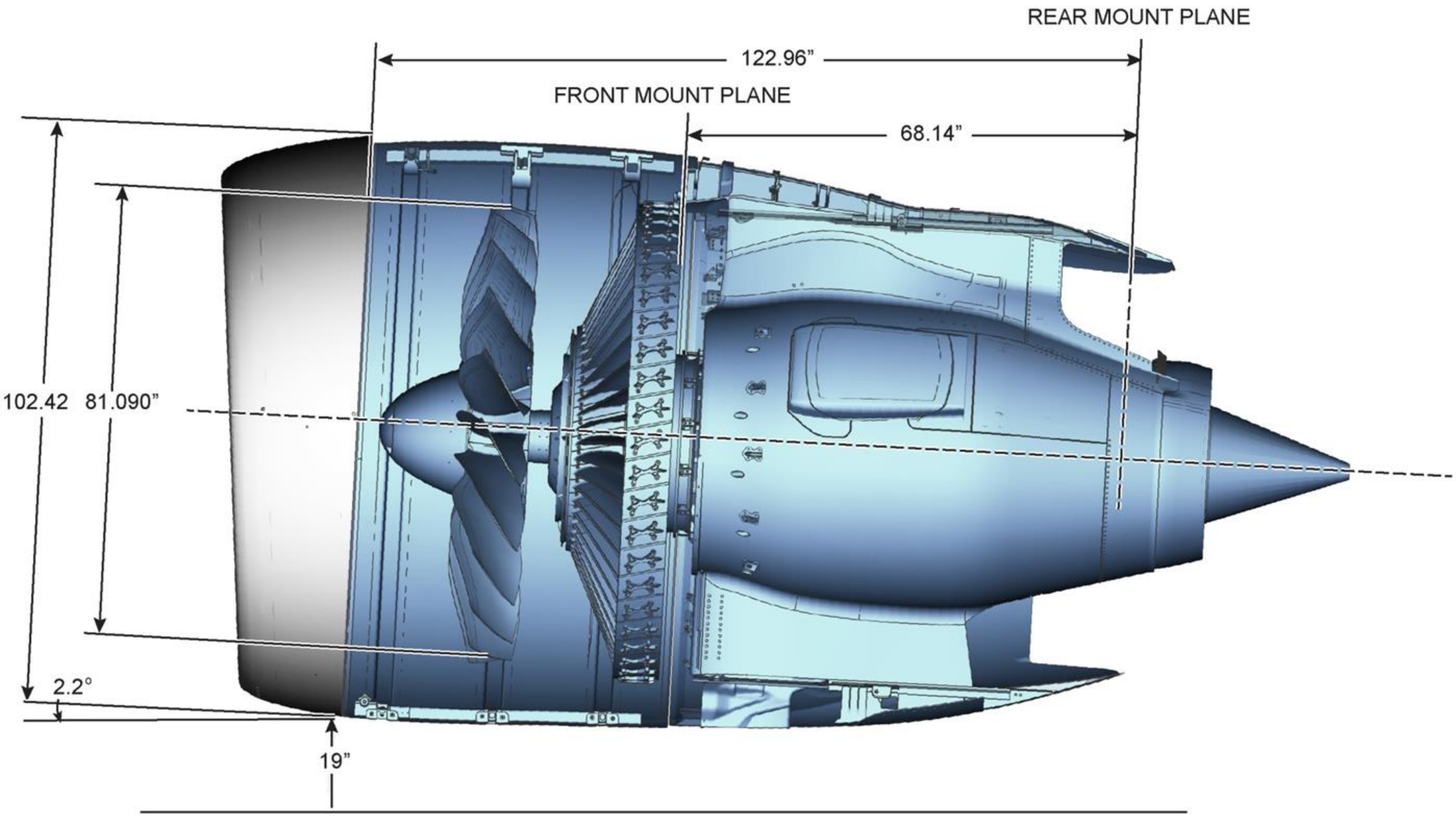


REAR MOUNT PLANE
122.96"
FRONT MOUNT PLANE
68.14"
102.42
81.090"
2.2°
19"

NACELLE SYSTEMS

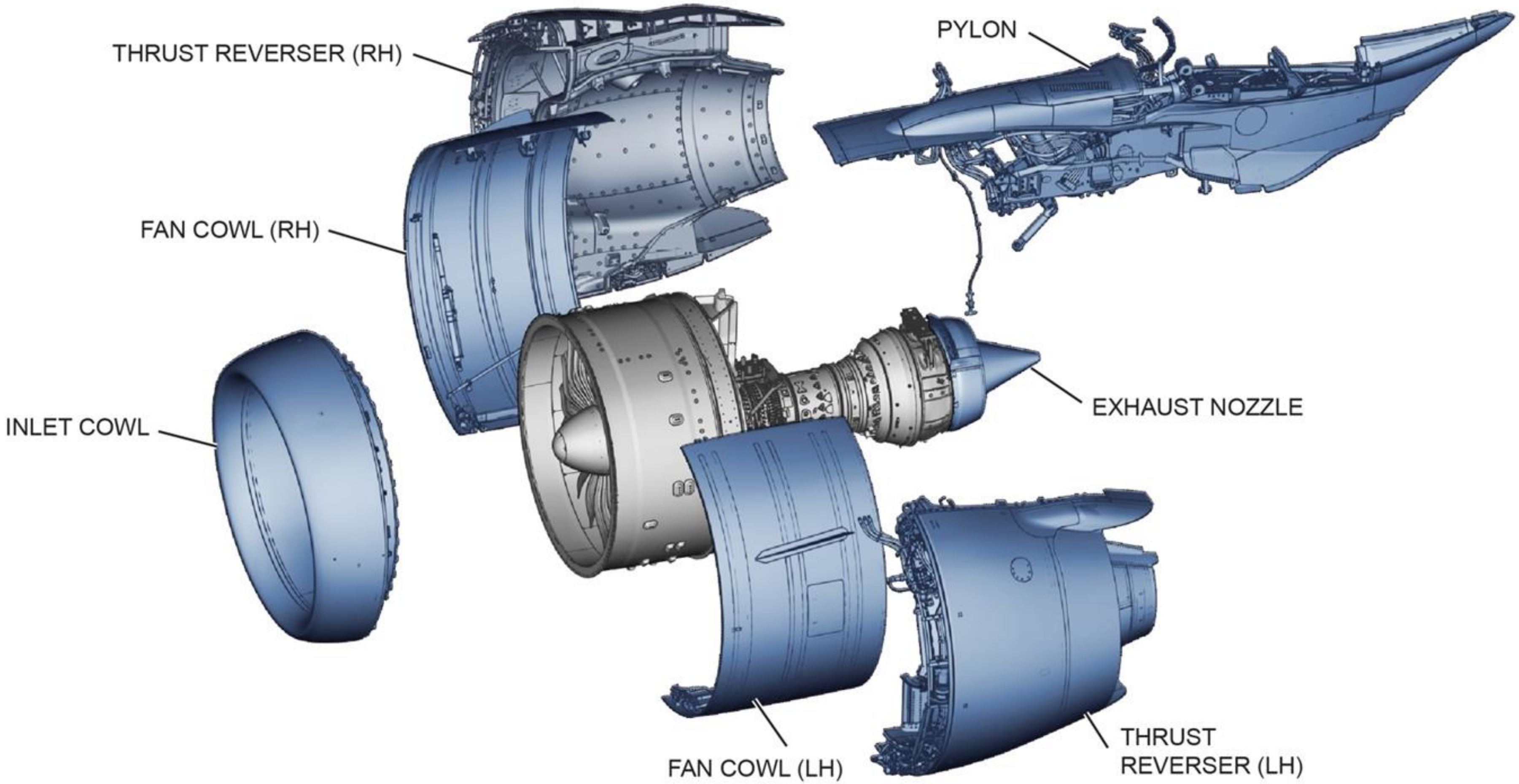
Nacelle systems components are mounted to the engine and to the pylon. They provide the engine with these capabilities:

an aerodynamic and protective enclosure for engine-mounted components

collection and discharge of oil, fuel, and hydraulic fluid from the engine and its components.

Nacelle system types and their components are listed in the table at right.

System Type	Components
Engine-mounted	• Inlet cowl • Exhaust nozzle • Exhaust plug
Pylon-mounted	• Fan cowl • Thrust reverser
Engine mounting	• Front mount • Rear mount • Thrust links


THRUST REVERSER (RH)
PYLON
FAN COWL (RH)
EXHAUST NOZZLE
INLET COWL
FAN COWL (LH)
THRUST
REVERSER (LH)

INLET COWL

Purpose:

The inlet cowl's aerodynamic barrel smooths airflow, providing uniform pressure as air reaches the fan.

Location:

The inlet cowl is secured to the engine fan case Flange A by the aluminium inlet attach ring.

The outer barrel is a two-piece assembly extending from the inlet lip interface to the leading edge of the fan cowl.

Two splice joints are located on the outer barrel at 5:00 and 7:00.

Description:

The cowl's outer skin provides even airflow across the engine nacelle.

The inner skin forms the engine inlet and acoustic treatment.

The forward bulkhead and aft bulkhead provide impact protection and structural support for the inlet assembly.

Lightning strike protection is provided by an expanded copper screen layer impregnated into the outer barrel assembly.

A panel in the outer barrel provides access for maintenance of the Thermal Anti-Ice (TAI) duct that supplies the inlet lip with hot air.

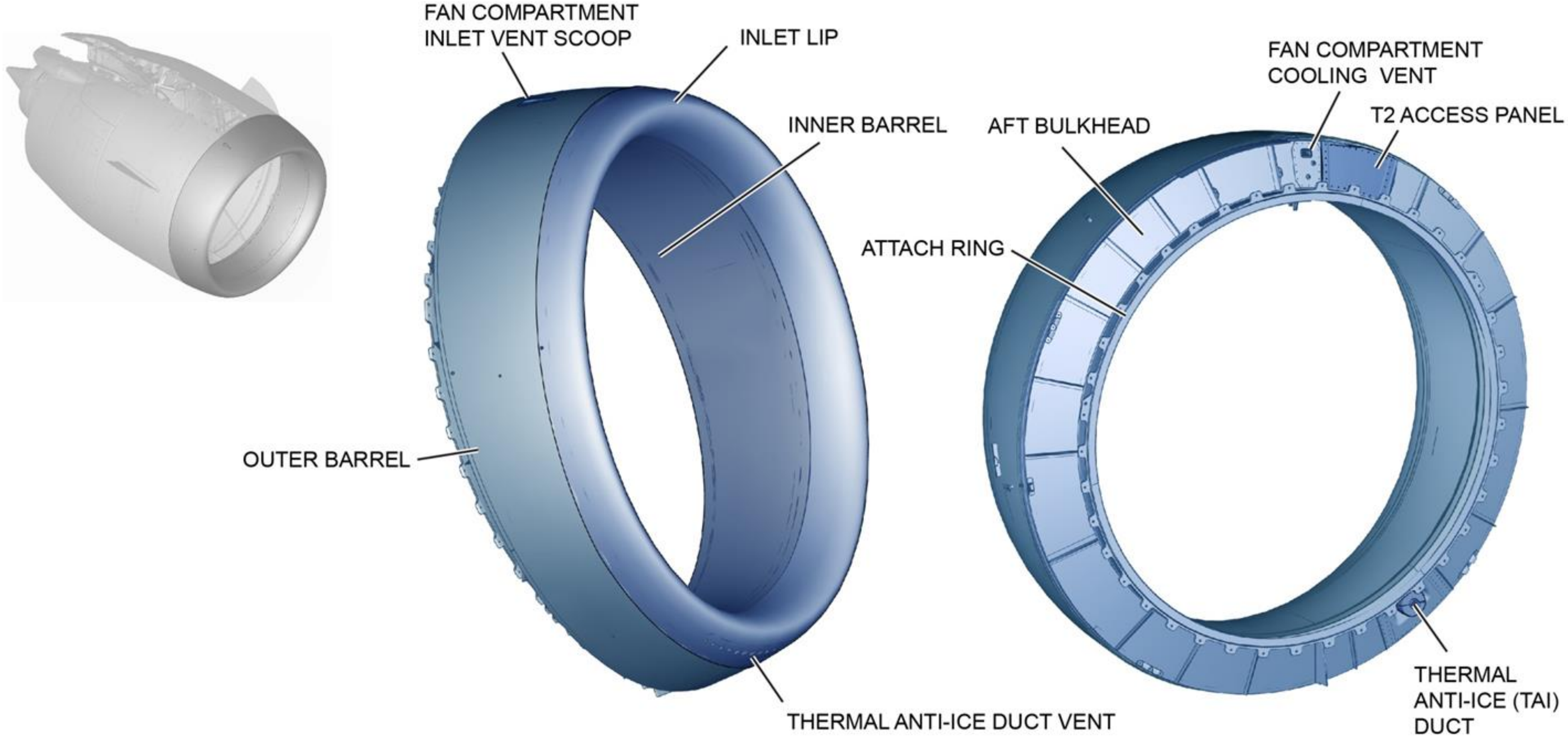
Anti-ice air exits the TAI vent located at 6:00 on the inlet lip.

Opening the right fan cowl on the aft bulkhead provides access to the anti-ice supply line.

A second panel serves the T2 probe and the wiring harness and sense line that are routed aft across the inner barrel to the aft bulkhead mounted interface.

A small flush inlet vent scoop located on the inlet outer barrel provides fan compartment cooling.

The inner barrel has gravity drainage holes embedded within the core.


FAN COMPARTMENT
INLET VENT SCOOP
INLET LIP
INNER BARREL
OUTER BARREL
THERMAL ANTI-ICE DUCT VENT
FAN COMPARTMENT
COOLING VENT
T2 ACCESS PANEL
AFT BULKHEAD
ATTACH RING
THERMAL
ANTI-ICE (TAI)
DUCT

FAN COWL

Purpose:

The fan cowl provides aerodynamic smoothness and a protective enclosure for the engine fan case and accessories. Fan cowl doors provide maintenance access to components and systems shown below.

- Anti-ice temperature and pressure sensors
- Electronic Engine Control EEC
- Prognostics and Health PHMU Management Unit
- Pylon disconnects
- Ignition exciter box
- Thrust reverser torque box
- Thrust Reverser Actuation TRAS System

Location:

The fan cowl covers the engine fan cases and is positioned between the inlet and reverser cowls.

CAUTION:

DO NOT OPEN THE FAN COWL IF THE WING LEADING EDGE SLATS ARE EXTENDED. DAMAGE TO THE FAN COWL, WING LEADING EDGE SLATS AND WING CAN OCCUR.

Description:

Fan cowl doors are a one-piece structure. Two fan cowl axial locators per door align the cowls as they close.

A copper mesh is embedded in the fan cowl laminate for lightning strike protection. Cowl doors are manually opened, and held open with forward and aft Hold Open Rods (HOR).

The fan cowl is secured to the pylon above the engine by pins installed through the cowl door hinges and pylon fittings.

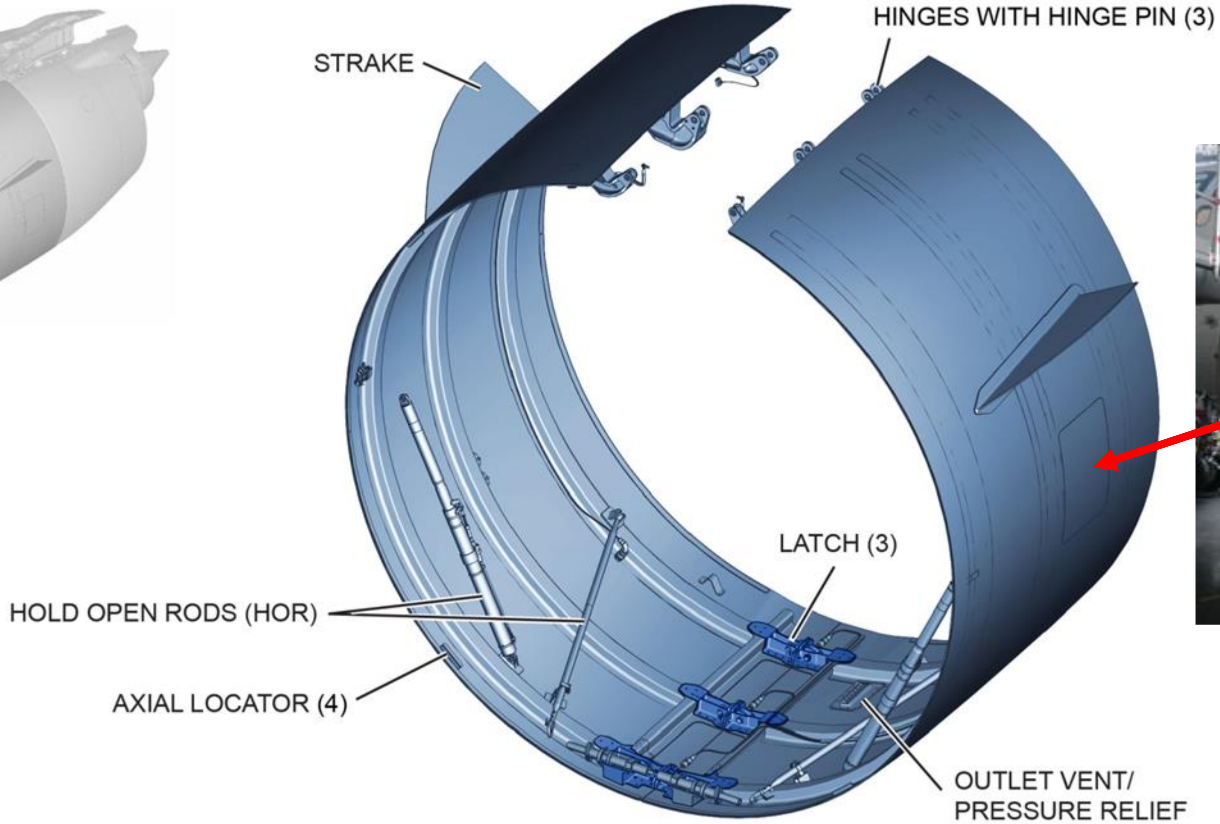
The fan cowls are also secured beneath the engine by three tension latches. Visual indicators on the latch handles show when the latches have not been properly secured.

An aerodynamic strake deflects airflow as required in certain manoeuvres related to aircraft performance.

The strake is mounted to the fan cowl outer surface on the inboard and outboard side.

A fan cowl vent provides overpressure protection in the event of a burst anti-ice duct. Drain holes at the bottom of the fan cowls provide fluid drainage.

Each door has three hoist provisions used for removal and installation.


STRAKE
HINGES WITH HINGE PIN (3)
LATCH (3)
HOLD OPEN RODS (HOR)
AXIAL LOCATOR (4)
OUTLET VENT/
PRESSURE RELIEF


air astana
NO GRAB

CAUTION:

DO NOT LEAVE THIS JOB AFTER UNLATCHING THE FAN COWLS. IF YOU ARE CALLED AWAY PRIOR TO OPEN ONE COWL DOOR, THEN EITHER OPEN ONE COWL DOOR OR RE-LATCH THE LATCHES BEFORE WALKING AWAY FROM THIS ENGINE.

CAUTION: WHEN YOU OPEN, OR CLOSE THE FAN COWL AFT LATCH (L3),

OBEY THESE INSTRUCTIONS:

DO NOT OPEN THE LATCH HOOK MORE THAN NECESSARY TO DISENGAGE FROM OR ENGAGE THE KEEPER.

DO NOT MOVE THE LATCH HOOK TOO MUCH IN THE DIRECTION OF THE LATCH HANDLE OR PUT THE LATCH HOOK AGAINST THE LATCH HANDLE.

MAKE SURE THAT THE ANGULAR POSITION OF THE LATCH HOOK IS A MINIMUM OF 90 DEGREES FROM THE LATCH HANDLE.

IF YOU DO NOT OBEY THESE INSTRUCTIONS, THE LATCH CAN HIT THE ENGINE OIL TUBE AND CAUSE DAMAGE.

NOTE: ALL AIRCRAFT SHOULD HAVE NOW BEEN MODIFIED TO STOP THIS

CAUTION:

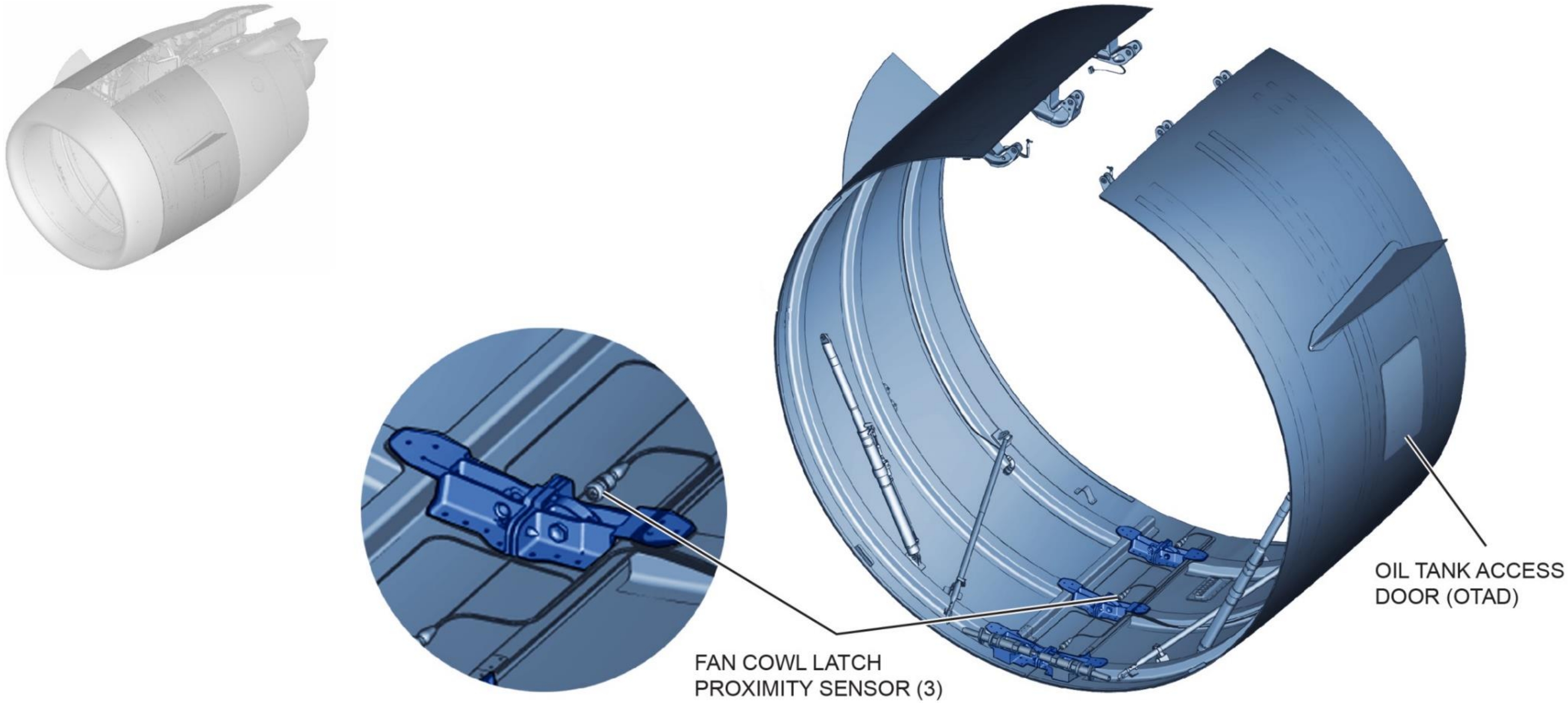
DO NOT LIFT THE FAN COWL DOOR MORE THAN 52 DEGREES FROM THE VERTICAL.

DAMAGE TO THE FAN COWL DOOR OR PYLON CAN OCCUR.

CAUTION:

WHEN YOU OPEN, OR CLOSE THE FAN COWL DOOR, BE CAREFUL NOT TO PUSH THE DOOR FORWARD OR AFT.

IF YOU DO THIS, THE DOOR CAN HIT COMPONENTS AND CAUSE DAMAGE TO THEM OR PREVENT CORRECT ENGAGEMENT OF THE AXIAL LOCATORS.



CAUTION: Latch 3 on the Fan Cowls can damage oil lines if improperly latched during maintenance opening and closing. All should have now been modified

Description

The Oil Tank Access Door (OTAD) provides quick access to the oil tank, allowing oil service without opening the cowling.

The OTAD is hinged at the front edge and secured with two latches that provide redundancy at the aft edge of the panel.

Each of three fan cowl door latches has a fan cowl door proximity sensor to alert the ground crew to the fan cowls’ position.

Each sensor can detect whether the relative latch is locked, to avoid any fan cowl door loss in flight.


NO STEP


WARNING

THRUST REVERSER

Thrust reverser cowl doors are comprised of two halves that are mechanically independent.

The halves hinge at the pylon, latching together along the bottom split line.

They can be opened using the Door Opening System (DOS) by means of a hydraulic hand pump.

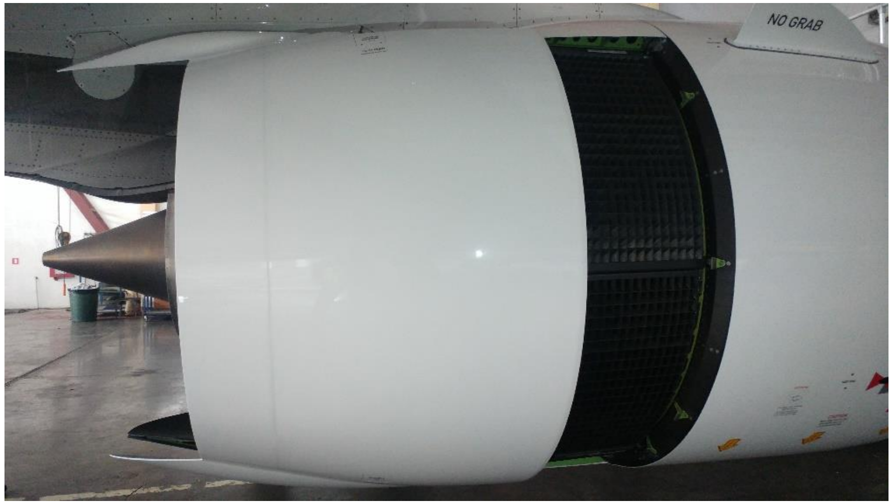
Each door is equipped with a Hold Open Rod (HOR).

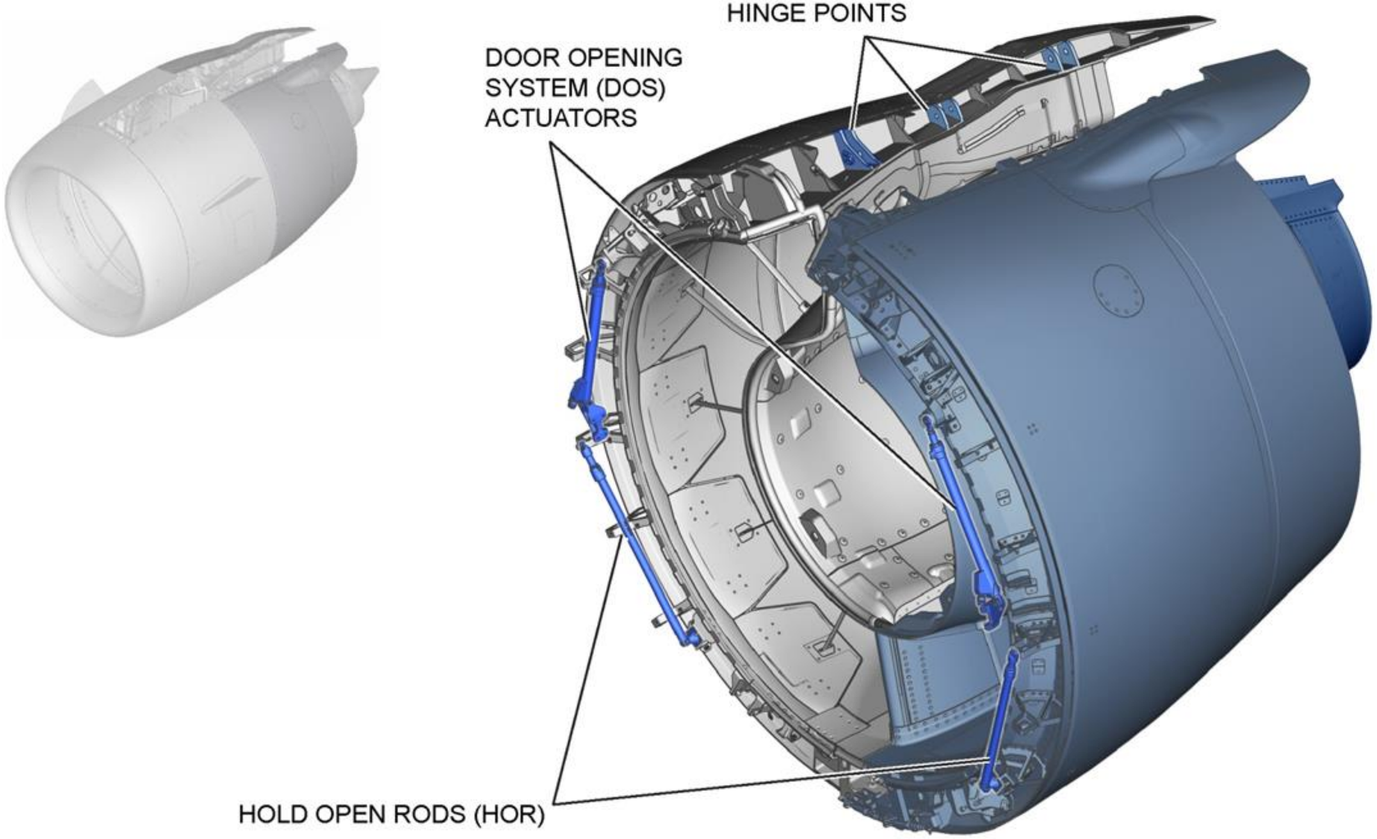
When stowed, the thrust reverser provides a smooth surface for the fan exhaust air to produce forward thrust.

When deployed, the thrust reverser redirects the fan exhaust air to produce reverse thrust that assists in braking.

Each thrust reverser door is attached to the pylon.

The two thrust reverser halves open at the 6 o'clock location and rotate around the 12 o'clock hinge beam to give access to the engine for maintenance.




HINGE POINTS
DOOR OPENING
SYSTEM (DOS)
ACTUATORS
HOLD OPEN RODS (HOR)

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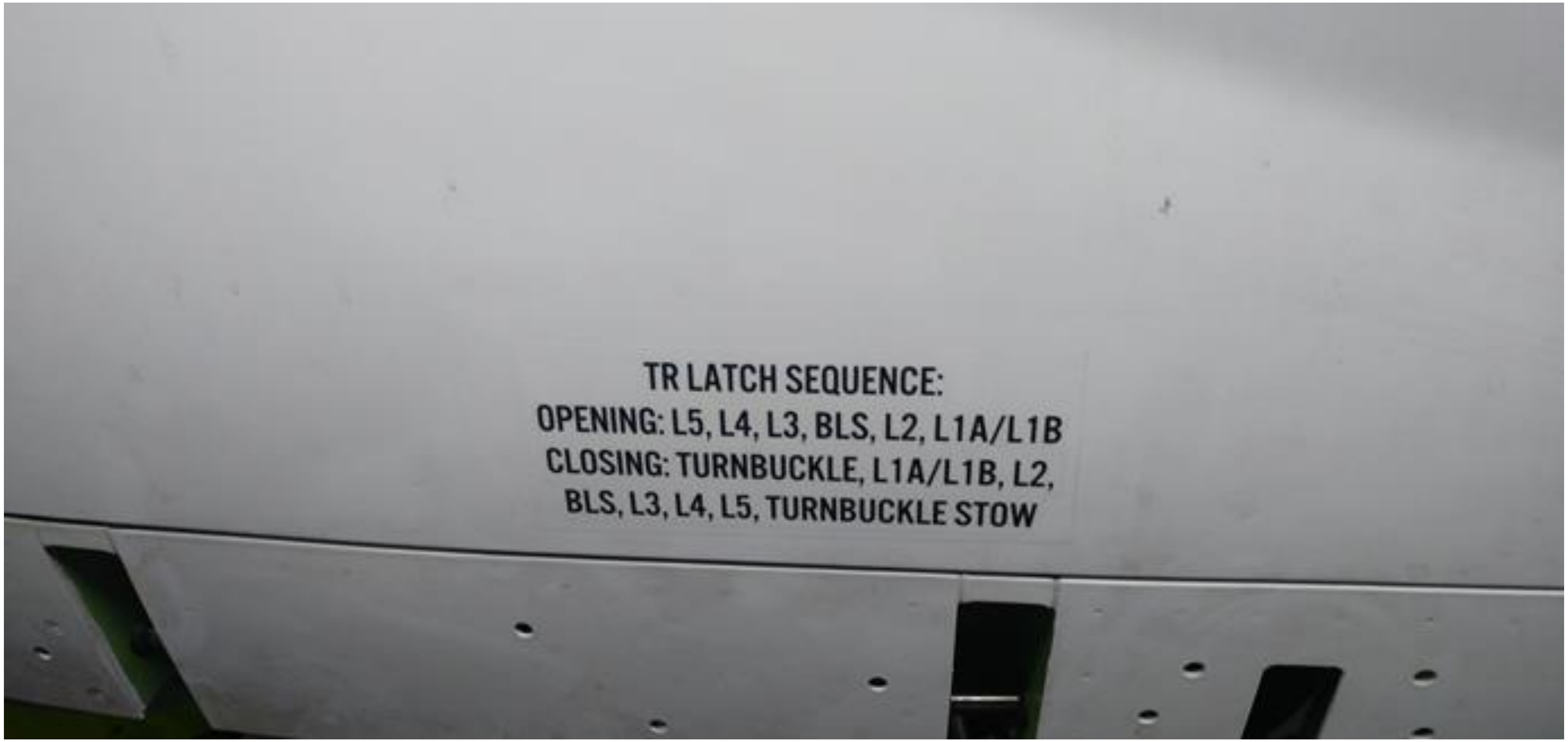

TR LATCH SEQUENCE:
OPENING: L5, L4, L3, BLS, L2, L1A/L1B
CLOSING: TURNBUCKLE, L1A/L1B, L2,
BLS, L3, L4, L5, TURNBUCKLE STOW

STRAKES

Purpose:

Strakes are mounted to the fan cowl outer surface to improve flight characteristics by controlling airflow.

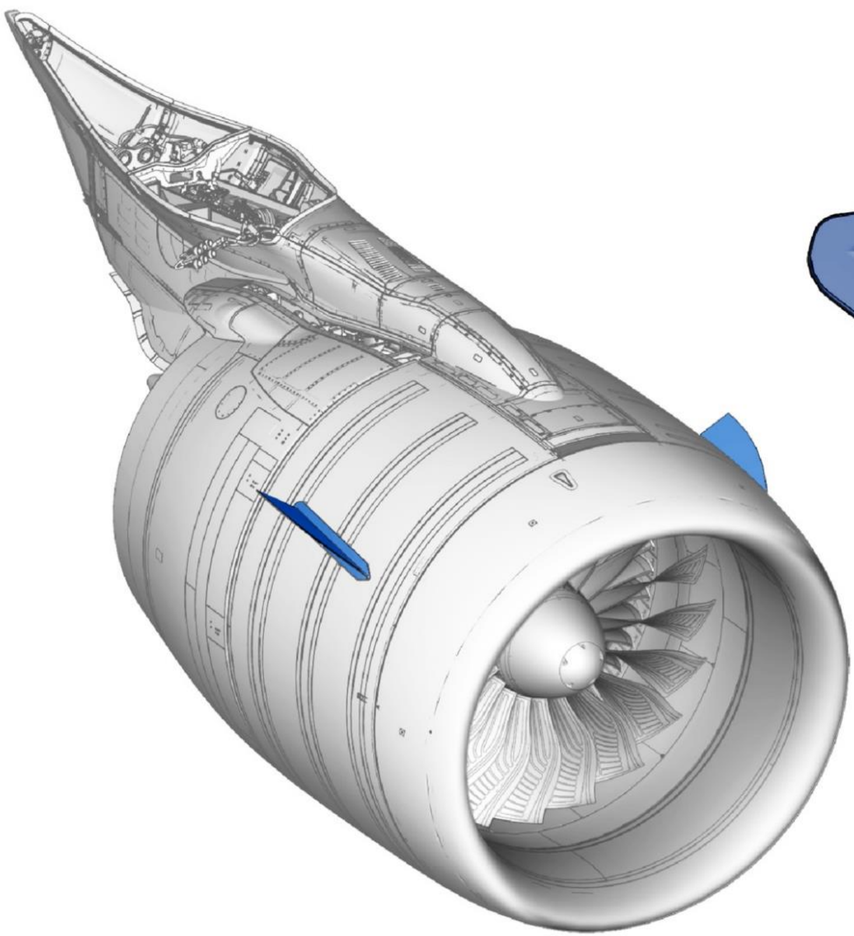
Location:

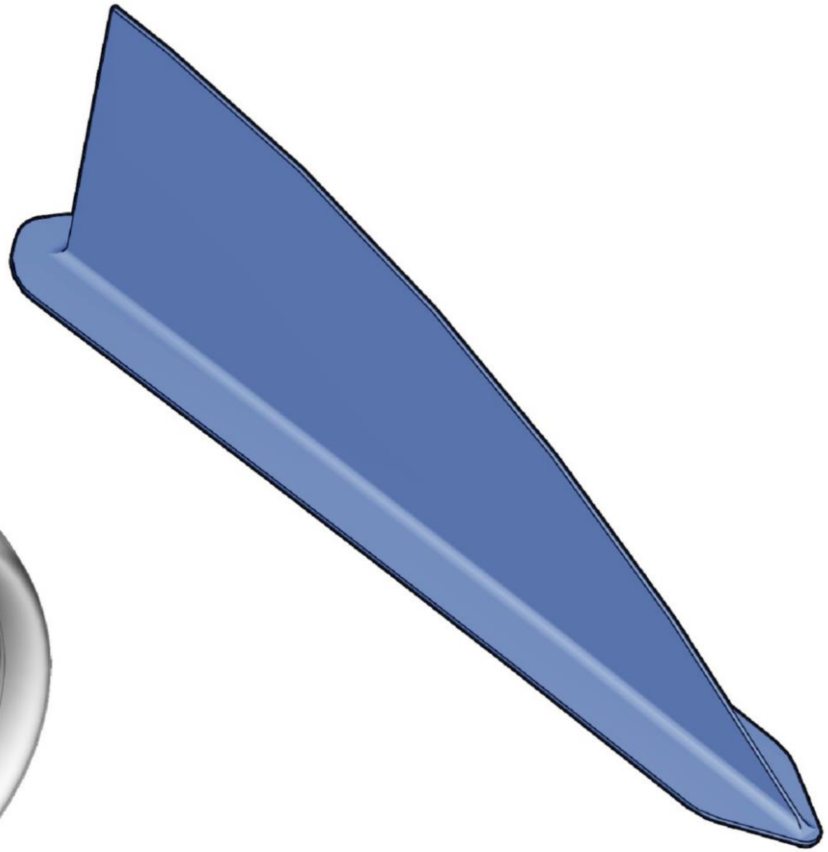
Strakes are mounted to both the left and right fan cowl doors.

Description:

Strakes decrease the turbulence of the airflow between the fan cowl door assembly and the wing.

The strake is attached to the inboard and outboard fan cowl door by 14 fasteners engaged into floating nut plates, located on the fan cowl interior skin.





ENGINE MOUNTS

The engine mounts transfer engine loads to the pylon.

Mount assemblies have four functions:

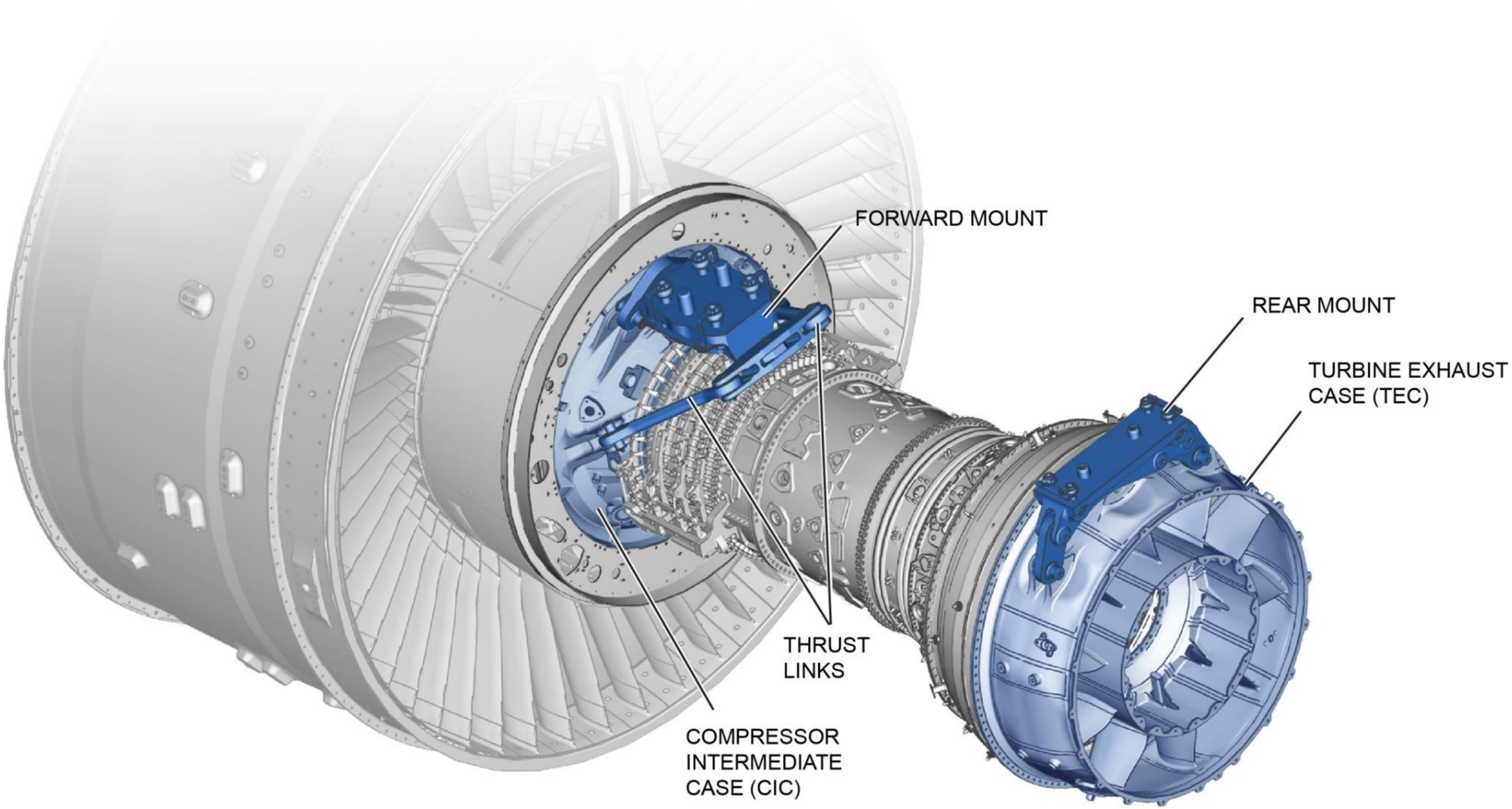
- support the weight of the engine
- transmit the thrust of the engine to the pylon
- prevent the engine from turning on its axis
- hold lateral loads.

Two mount assemblies and one sub-assembly are located between the engine and the pylon: the forward and aft mounts, and the thrust links, respectively.

The forward mount assembly is connected at the top of the engine's Compressor Intermediate Case.

The aft mount assembly is connected at the top of the engine's Turbine Exhaust Case.

The thrust link sub-assembly is connected to the Compressor Intermediate Case at approximately 9:30 and at 2:30, and to the forward mount through a balance beam.


FORWARD MOUNT
REAR MOUNT
TURBINE EXHAUST
CASE (TEC)
THRUST
LINKS
COMPRESSOR
INTERMEDIATE
CASE (CIC)

FORWARD ENGINE MOUNT

The forward mount is attached to the Compressor Intermediate Case, and is connected to the pylon.

The forward mount supports side and vertical loads using a two-link arrangement with bolts loaded in shear.

Main components of the forward mount assembly are below.

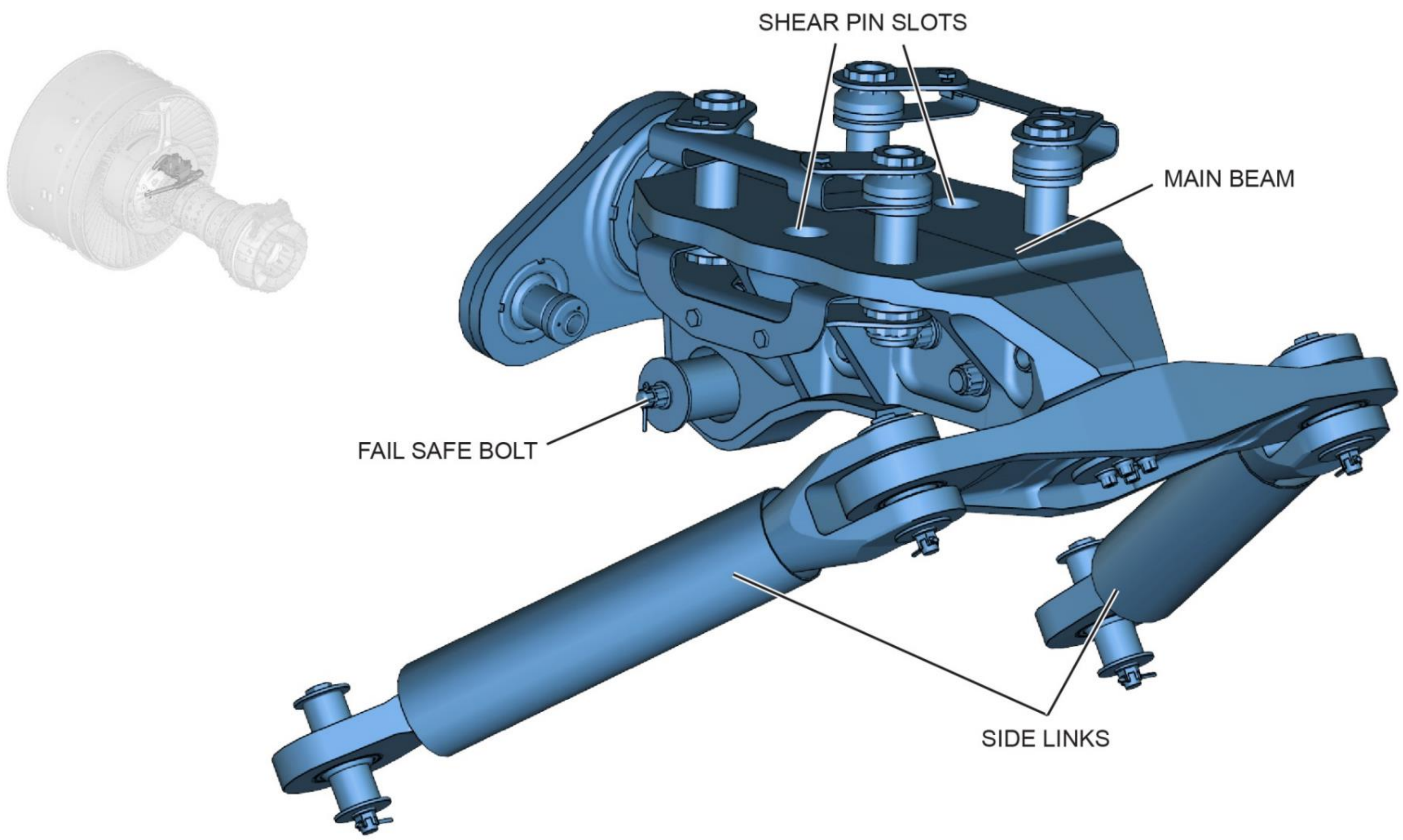
- Main beam
- Side links (2)
- Shear pin slots (2)
- Fail-safe bolt

The side and vertical loads at the forward mount couple with the aft mount loads to support overall engine pitch and yaw.

Side links provide the primary load paths (Thrust) from the fan case into the front beam.

The forward mount is attached to the pylon with four bolts and two shear pins, which transmit vertical and shear loads into the pylon.

The mount bolts use captive barrel nuts to ease removal.


SHEAR PIN SLOTS
MAIN BEAM
FAIL SAFE BOLT
SIDE LINKS

AFT MOUNT ASSEMBLY

The aft mount is attached to the Turbine Exhaust Case (TEC) and reacts to engine fore-aft, side, vertical, and roll loads.

Main components of the aft mount assembly are below.

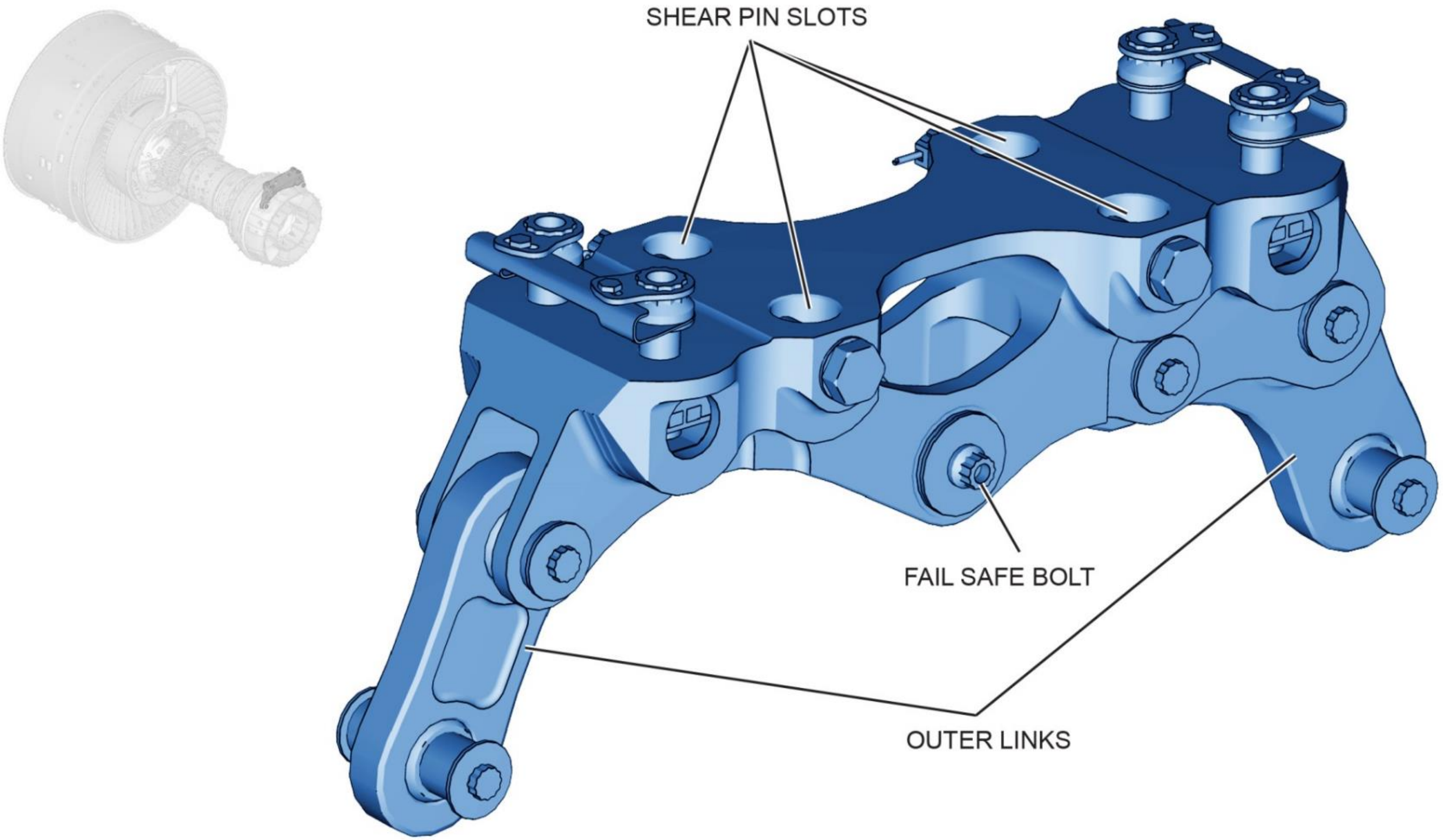
Main beam
Outer links (2)
Shear pin slots (4)
Fail safe bolt

The two outer links are assembled to the beam with four shear bolts.

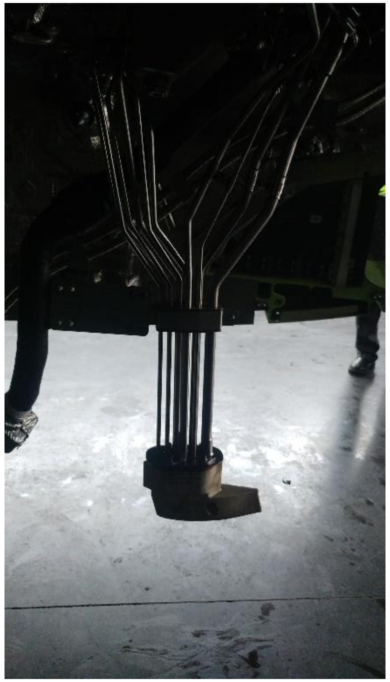
Each outer link is attached to the TEC with one shear bolt.

The centre link is attached directly to the TEC with another shear bolt.

The failure of any one link on the rear mount, including the thrust links, will cause the system to transfer loads to a secondary load path.


SHEAR PIN SLOTS
FAIL SAFE BOLT
OUTER LINKS

ENGINE DRAIN SYSTEM



The Engine Drain System collects and discharges oil, fuel, and hydraulic fluid from the engine and pylon, delivering residuals to the lower bifurcation drain mast through dedicated drain tubes.

Drain components are located on the left and right sides, and at the bottom of the engine.

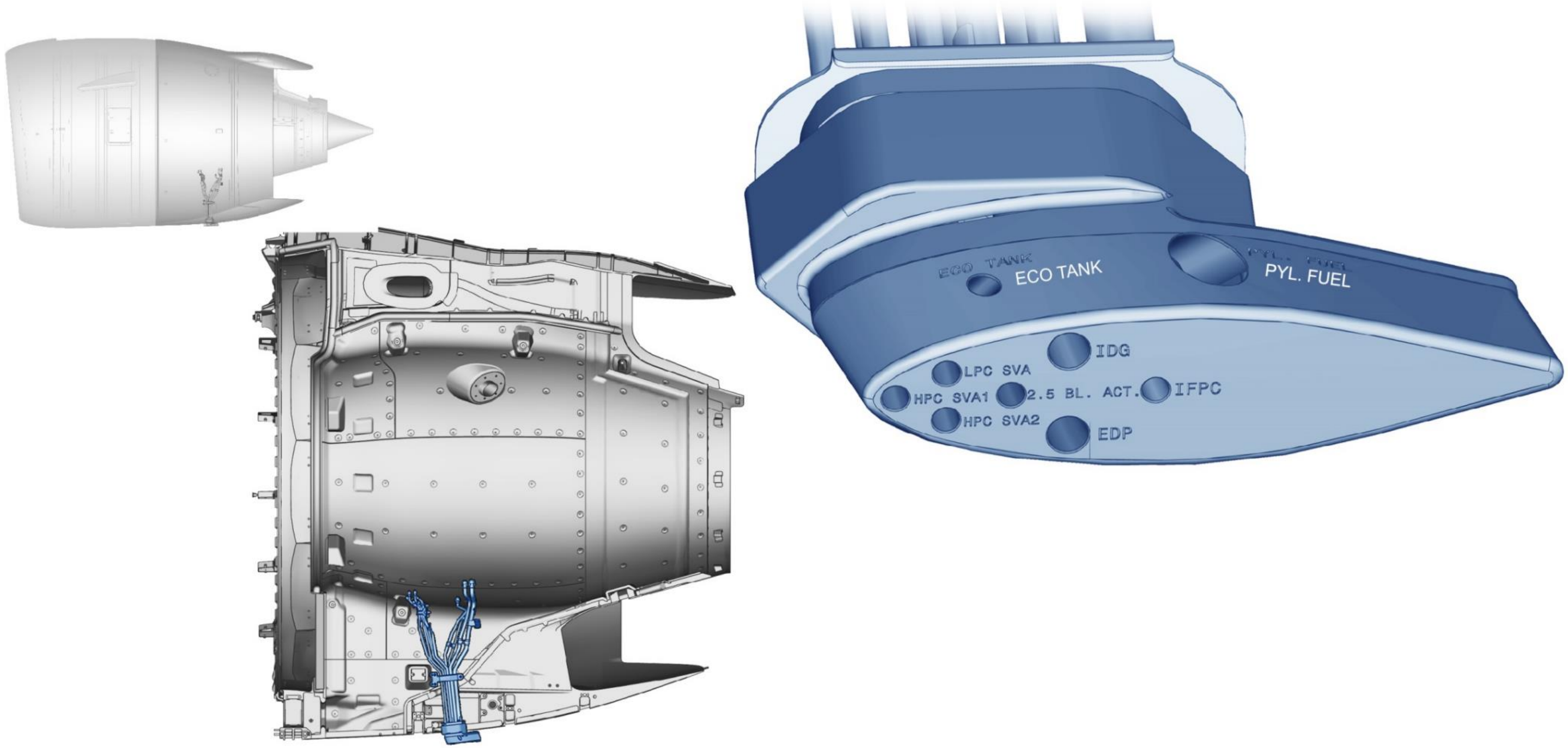
Drain paths have gaps around the Latch Access Panel (LAP) and eight drain holes in the lower bifurcation fixed/access panels.

The LAP has outlets that allow Main Gearbox, engine component and pylon drain tubes to drain fluids overboard from the nacelle.

Related components from each of eight outlets are identified on the pylon tube at the drain mast and at placards on the LAP.

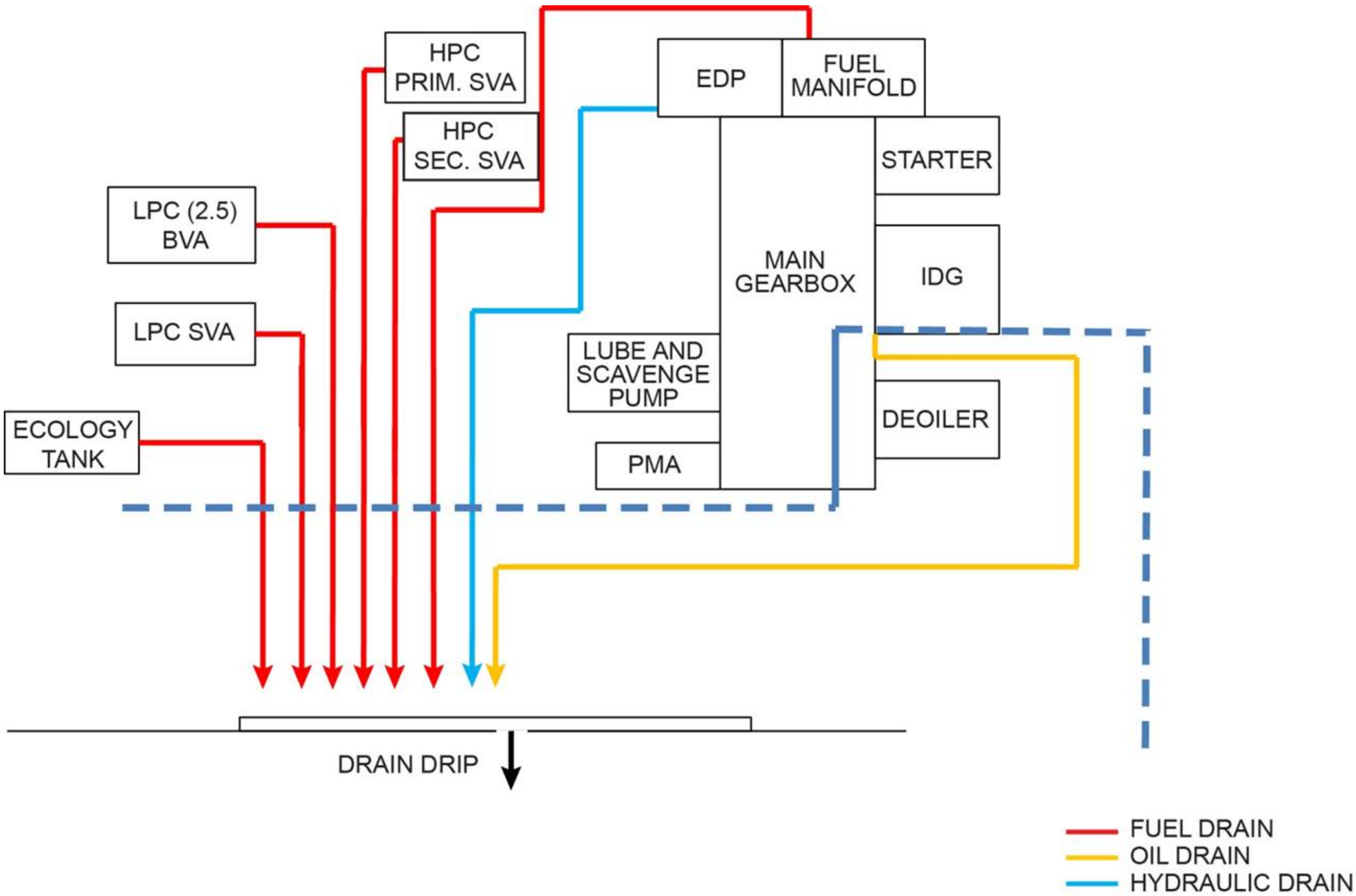
Engine components that drain through the drain mast are listed below.

- 2.5 bleed valve actuator
- HPC primary and secondary stator vane actuators
- LPC stator vane actuator
- Integrated Drive Generator IDG
- Integrated Fuel Pump and Control IFPC
- Hydraulic Engine Driven Pump EDP
- Ecology collector tank


ECO TANK
PYL. FUEL
IDG
LPC SVA
HPC SVA1
2.5 BL. ACT.
IFPC
HPC SVA2
EDP

Drain Location	Fluid	Leakage Limit	
		CC/Hour	Drops/Minute
IFPC carbon seal	Oil	10	3.3
Hydraulic pump carbon seal			
IDG carbon seal			
2.5 bleed actuator	Fuel	15	5
LPC Stator Vane Actuator			
HPC Primary Stator Vane Actuator			
HPC Secondary Stator Vane Actuator			
IFPC seal		2	1

DRAIN MAST LEAKAGE LIMITS


HPC
PRIM. SVA
HPC
SEC. SVA
EDP
FUEL
MANIFOLD
STARTER
LPC (2.5)
BVA
MAIN
GEARBOX
IDG
LPC SVA
LUBE AND
SCAVENGE
PUMP
DEOILER
ECOLOGY
TANK
PMA
DRAIN DRIP
FUEL DRAIN
OIL DRAIN
HYDRAULIC DRAIN

ENGINE GROUND RUN WIND DIRECTIONS

The wind direction and velocity can change the stability of the engine.

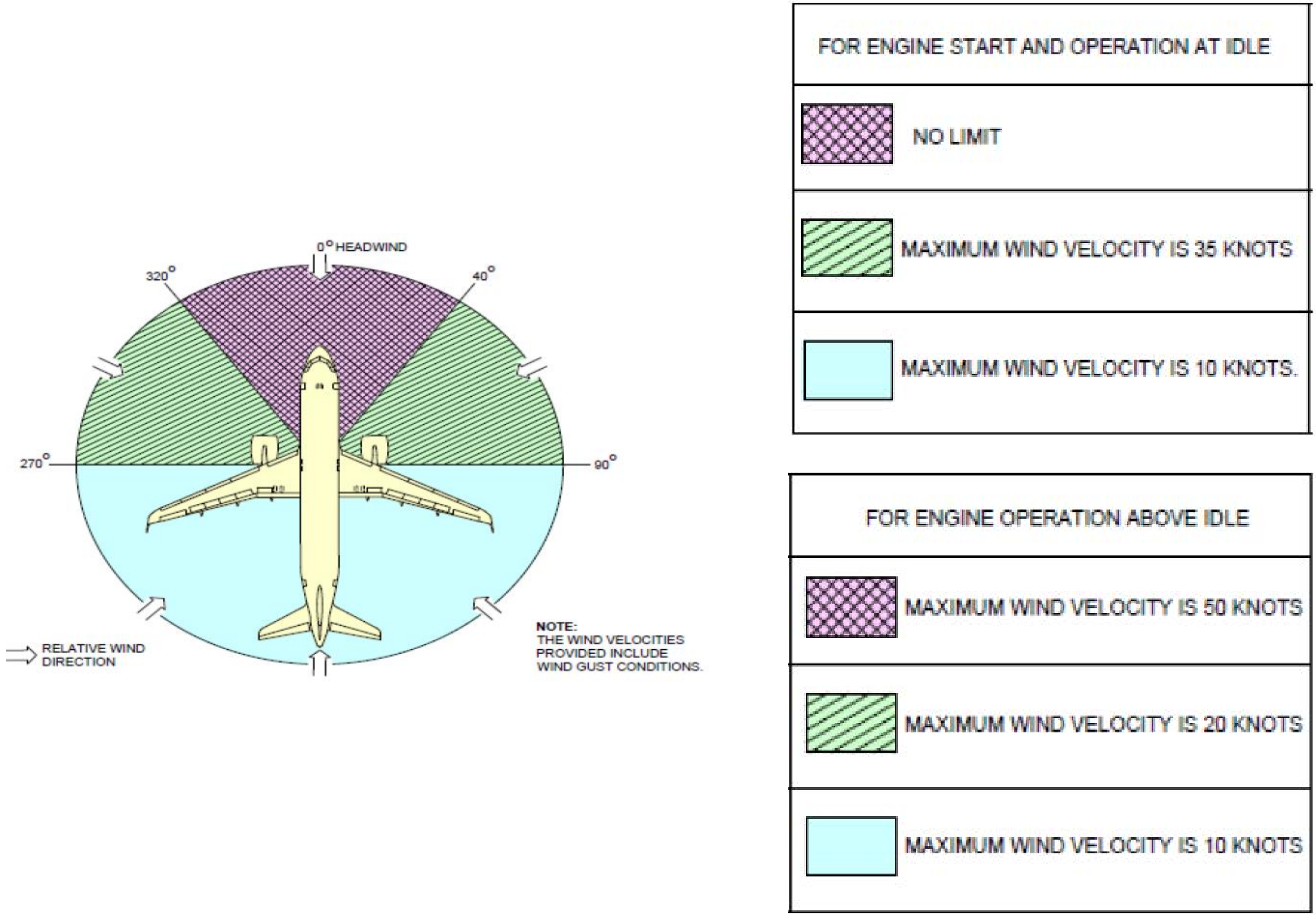
Make sure the engine is operated within the defined wind envelope.

1 The wind velocities shown are for constant wind conditions only.

2 Stop the engine operation if the engine N1 speed is not stable.

3 Stop the engine operation if, at steady state, the inlet noise increases or changes to a blow torch sound.

4 Stop the engine operation if, at steady state, the engine vibration increases.


0° HEADWIND
320°
40°
270°
90°
RELATIVE WIND DIRECTION
NOTE:
THE WIND VELOCITIES PROVIDED INCLUDE WIND GUST CONDITIONS.
FOR ENGINE START AND OPERATION AT IDLE
NO LIMIT
MAXIMUM WIND VELOCITY IS 35 KNOTS
MAXIMUM WIND VELOCITY IS 10 KNOTS.
FOR ENGINE OPERATION ABOVE IDLE
MAXIMUM WIND VELOCITY IS 50 KNOTS
MAXIMUM WIND VELOCITY IS 20 KNOTS
MAXIMUM WIND VELOCITY IS 10 KNOTS

ENGINE GROUND RUN DANGER ZONES

The high velocity, high temperature, and toxicity of discharged exhaust gases can be dangerous.

Jet wakes in the exhaust area can be significant.

Entry corridors and hazard areas are shown for personnel guidance when approaching an operating engine.

Authorized persons near the engine must only go near the engine at idle power and obey the entry corridor areas.

Do not operate the engine above idle power with persons in the entry corridor areas.

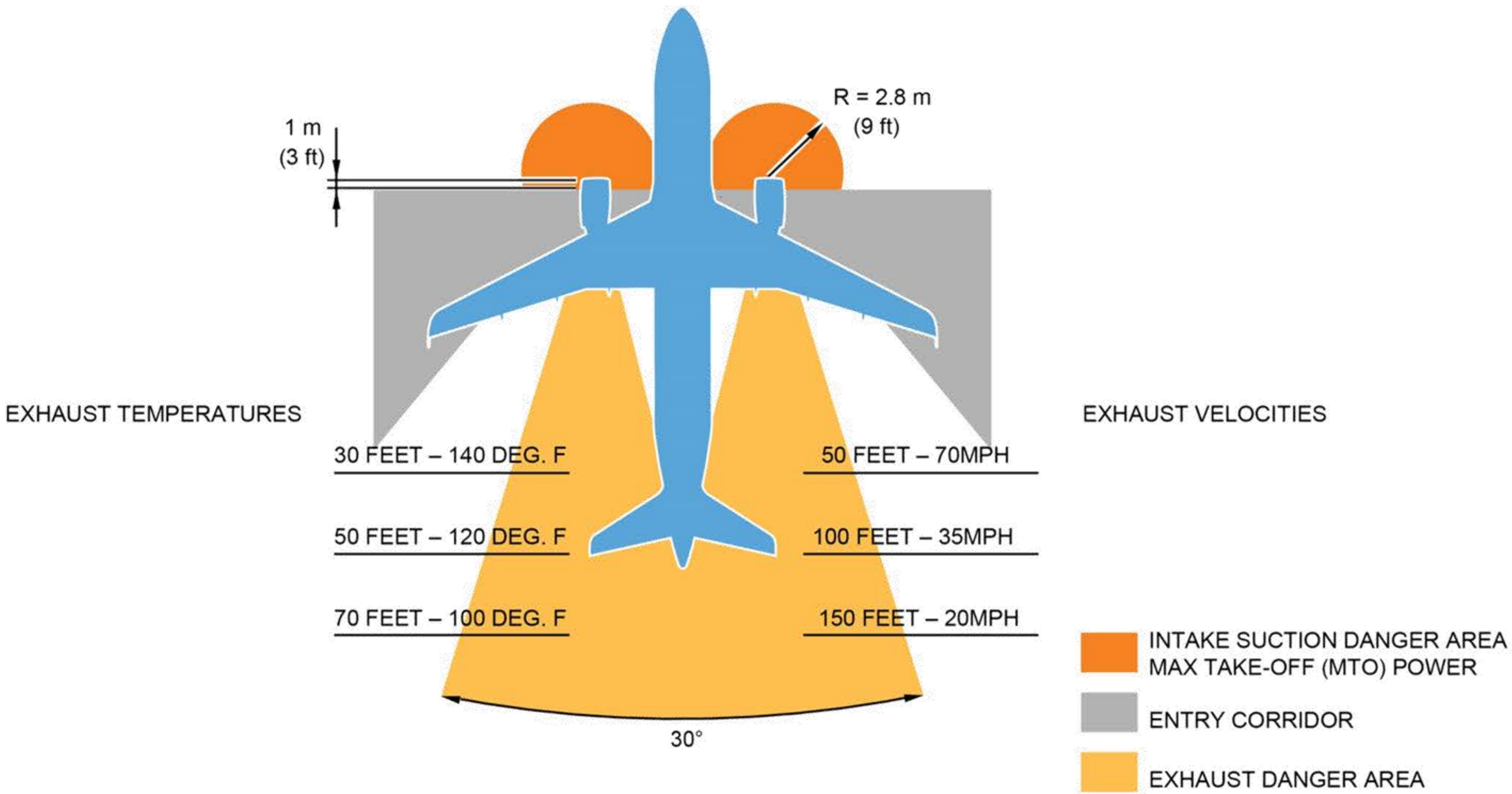
WARNING:

STAY AWAY FROM THE DANGER AREAS AT THE FRONT AND THE SIDES OF THE ENGINE DURING OPERATION. THE SUCTION IS SUFFICIENT AT THE AIR INTAKE COWL TO PULL A PERSON INTO (IN PART OR FULLY) THE ENGINE. THIS CAN KILL A PERSON OR CAUSE A BAD INJURY.

CAUTION:

REMOVE OR MAKE SAFE ALL LOOSE ITEMS BEFORE YOU DO WORK AROUND AN ENGINE THAT OPERATES. THE SUCTION IS SUFFICIENT AT THE AIR INTAKE COWL TO PULL HATS, LOOSE CLOTHING, GLASSES, AND WORK RAGS FROM YOUR POCKETS INTO THE ENGINE.

Do not operate the engine at minimum idle speed with the cowl doors open because damage to the cowl doors could result.



ENGINE DANGER ZONES AT GROUND IDLE

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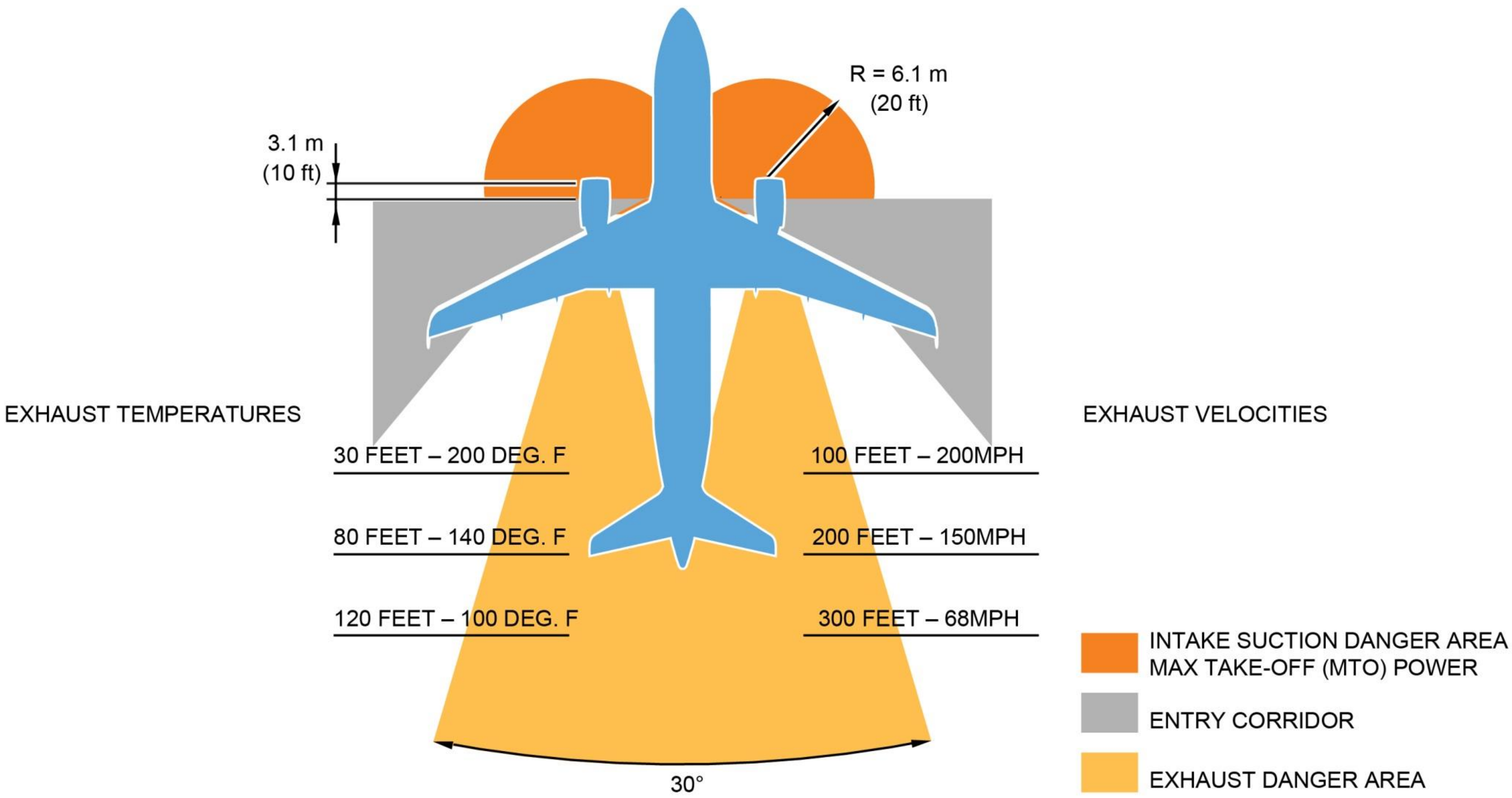
Do not operate the engine above idle power with persons in the entry corridor areas.



ENGINE DANGER ZONES AT MAX TAKE-OFF

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ENGINE CONSTRUCTION

GAS PATH CONFIGURATION

Gas path configuration is a term describing the engine modules that make up the primary path of airflow through the engine.

A module is an assembly of parts that can be installed or removed from the engine as a single unit.

Gas path modules and their stage counts are listed below.

Each stage is made up of a single rotor assembly and its complementing stator assembly.

Note that in the compressor section, the rotor precedes the stator. In the turbine section, the rotor follows the stator.

Module		Stage Count
Fan rotor		1
Fan Intermediate Case	FIC	N/A
Low Pressure Compressor	LPC	3
Compressor Intermediate Case	CIC	N/A
High Pressure Compressor	HPC	8
Diffuser and combustor		N/A
High Pressure Turbine	HPT	2
Turbine Intermediate Case	TIC	N/A
Low Pressure Turbine	LPT	3
Turbine Exhaust Case	TEC	N/A

ENGINE FLANGES

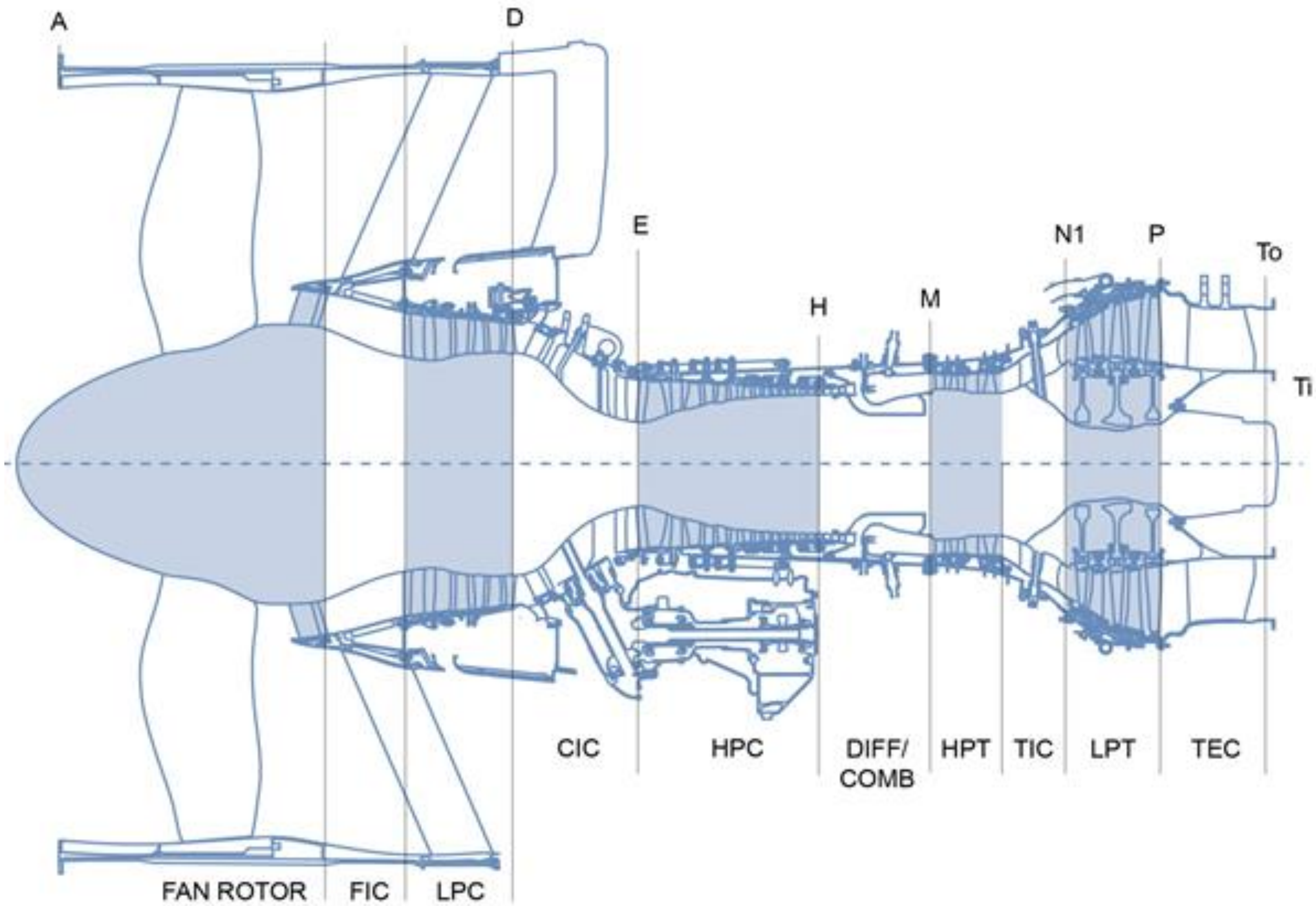
Engine flanges are external features of the engine case that serve various structural purposes, including:

- joining module assemblies together
- supporting the engine's streamlined enclosure known as the *nacelle*
- supporting the brackets used to mount engine components.

Flanges and the modules they support are detailed at right.

They are shown in conjunction on the graphic below.

Flange	Modules	
A	Inlet cowl attachment	
D	V-ring groove	
E	High Pressure Compressor	HPC
H	Diffuser case	
M	High Pressure Turbine	HPT
N1	Low Pressure Turbine	LPT
P	Turbine Exhaust Case	TEC
To	Exhaust sleeve nozzle attachment	
Ti	Exhaust plug attachment	


A
D
E
H
M
N1
P
To
Ti
FAN ROTOR
FIC
LPC
CIC
HPC
DIFF/
COMB
HPT
TIC
LPT
TEC

ENGINE STATIONS

Engine stations are locations in the gas path.

Key stations along the gas path have pressure probes and temperature sensors.

Signals from the probes and sensors are transmitted through the engine's electronic control component to the flight deck.

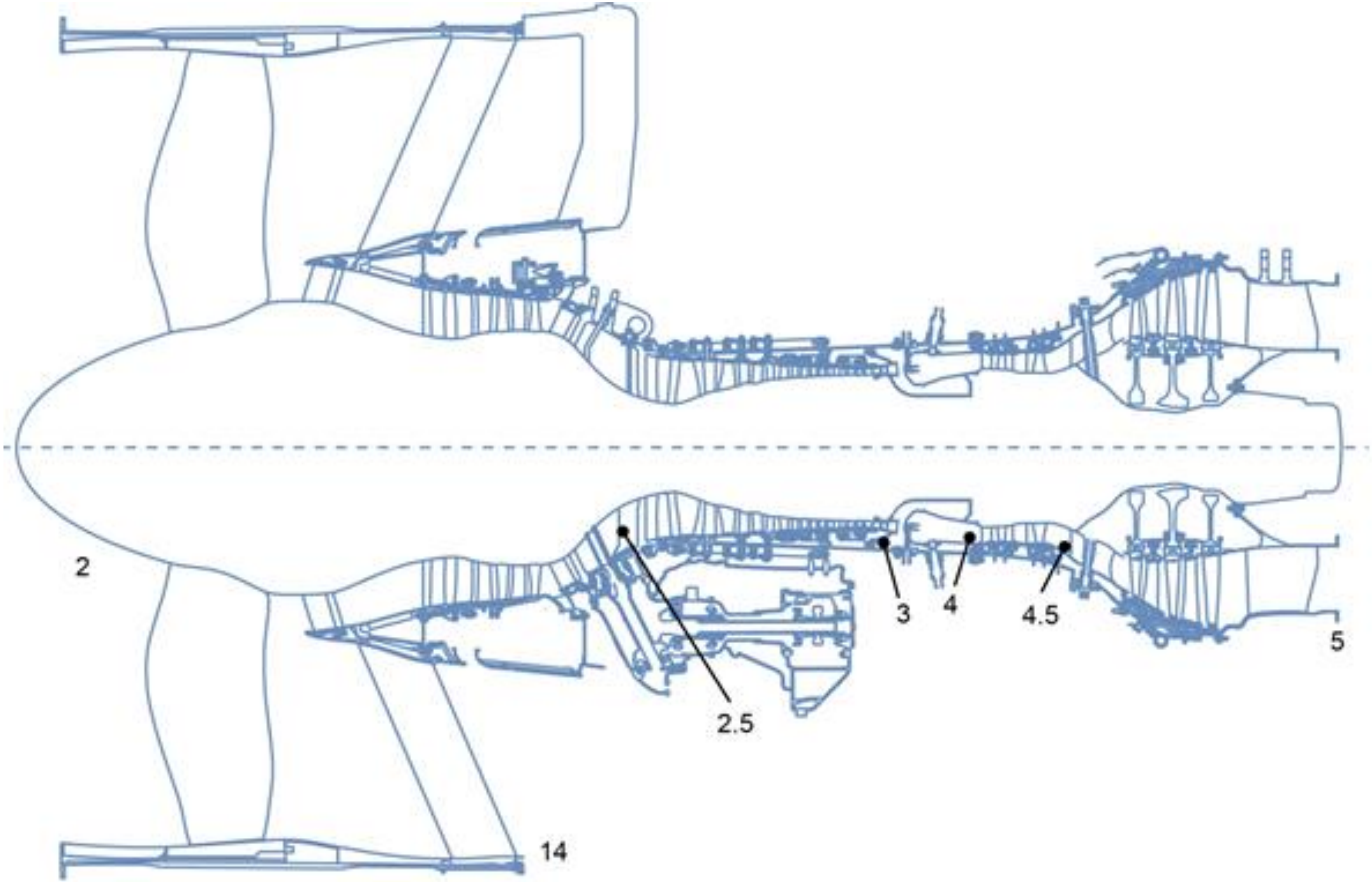
Stations are illustrated in the graphic below.

Each sensor uses the number of the engine station as part of its name.

Examples are shown below.

Sensor	Naming Convention
T3	T= Temperature 3 = Station 3
PT2.5	PT = Pressure and Temperature 2.5 = Station 2.5

Station	Location
2	Engine inlet
2.5	LPC exit
3	HPC exit
4	HPT inlet
4.5	HPT exit
5	Exhaust
14	Aft Fan Exit Guide Vane


2
2.5
3
4
4.5
5
14

ENGINE MAIN BEARINGS

Bearings support the weight of engine parts and permit one surface to roll over another with minimal friction and wear.

The weight of the parts is transmitted through balls or rollers that are contained by two raceways.

Bearings are designed from materials that can withstand extreme pressure, since they must absorb the axial and radial loads of rotating assemblies.

An axial load is transmitted parallel to the bearing shaft, and a radial load is applied perpendicular to the shaft.

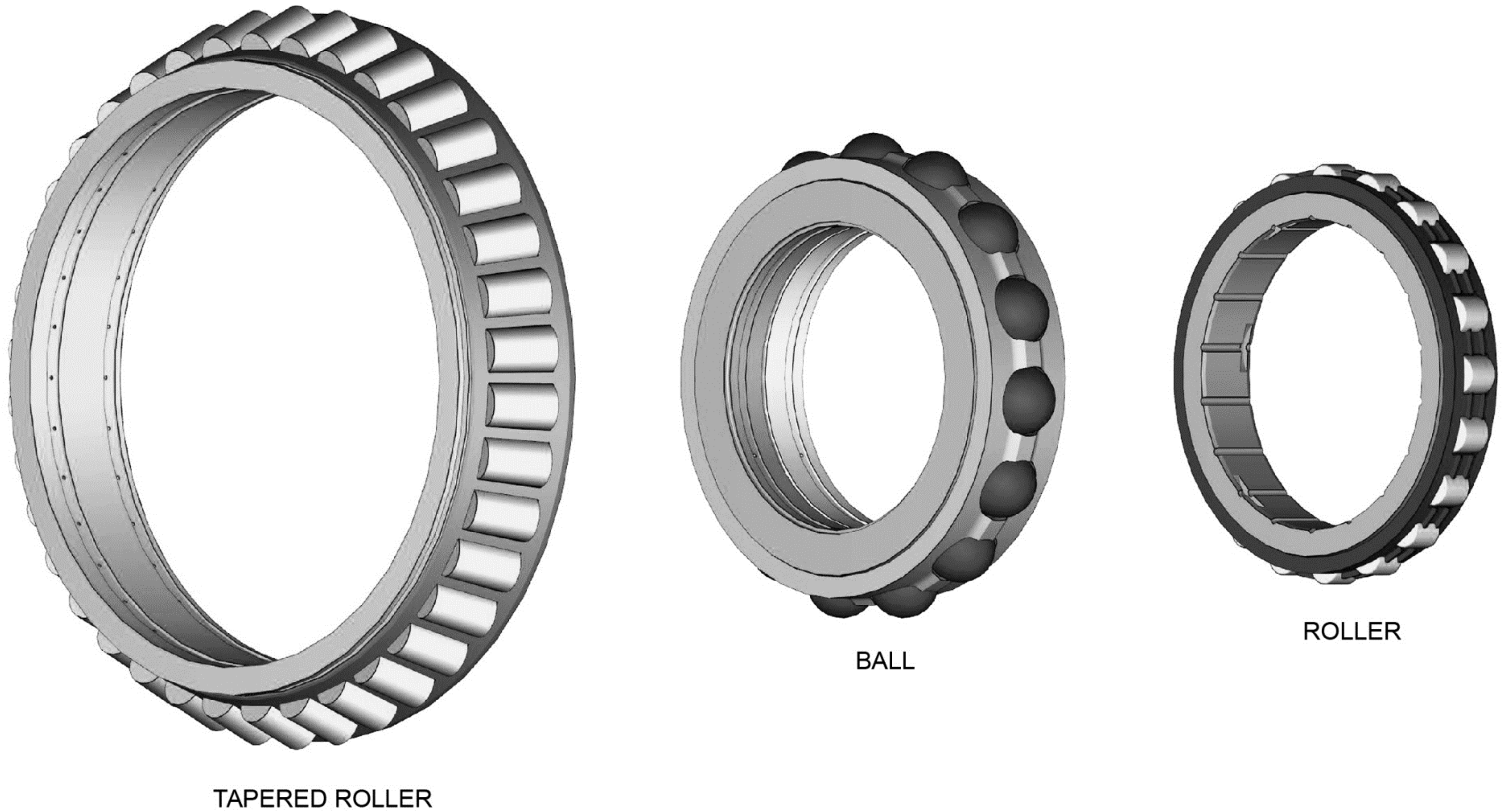
Bearings are lubricated, cooled, and cleaned by oil.

The PW1100G-JM uses three types of bearings, described in the chart. Each bearing type holds engine parts in alignment to transmit their load.

Note that tapered roller bearings operate like ball bearings, while requiring less space than standard roller bearings.

Bearing types are illustrated in the graphic below.

Bearing	Alignment and Load
Roller	Radial
Ball	Axial and radial
Tapered roller	


TAPERED ROLLER
BALL
ROLLER

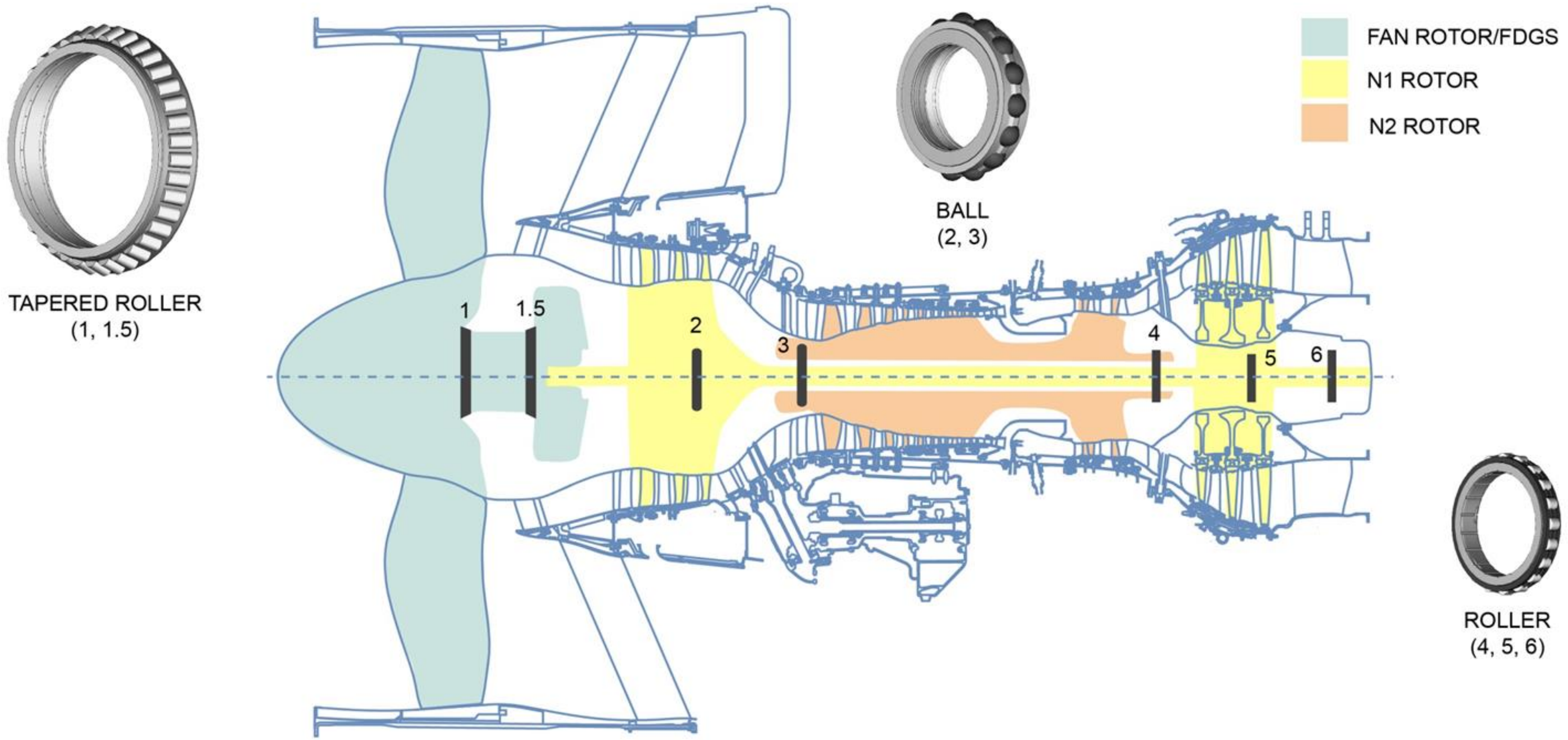
ENGINE MAIN BEARINGS

Five compartments contain a total of seven bearings. Descriptions are shown at right.

Oil-damped bearings use a thin film of oil between the outer race and the bearing support to reduce vibration.

Note: the low pressure and high-pressure rotors are often referred to as *N1* and *N2*, respectively.

Bearing	Type	Oil Damped	Support Function
1	Tapered roller	✓	Fan rotor and Fan Drive Gear System (FDGS)
1.5			
2	Ball	✓	Front of N1 rotor (LPC)
3		✓	Front of N2 rotor (HPC)
4	Roller	✓	Rear of N2 rotor (HPT)
5			Rear of N1 rotor (LPT)
6		✓	


TAPERED ROLLER
(1, 1.5)
BALL
(2, 3)
FAN ROTOR/FDGS
N1 ROTOR
N2 ROTOR
1
1.5
2
3
4
5
6
ROLLER
(4, 5, 6)

ENGINE MAIN BEARINGS

Bearing Compartment Hardware

Each compartment uses carbon seals to prevent oil leakage.

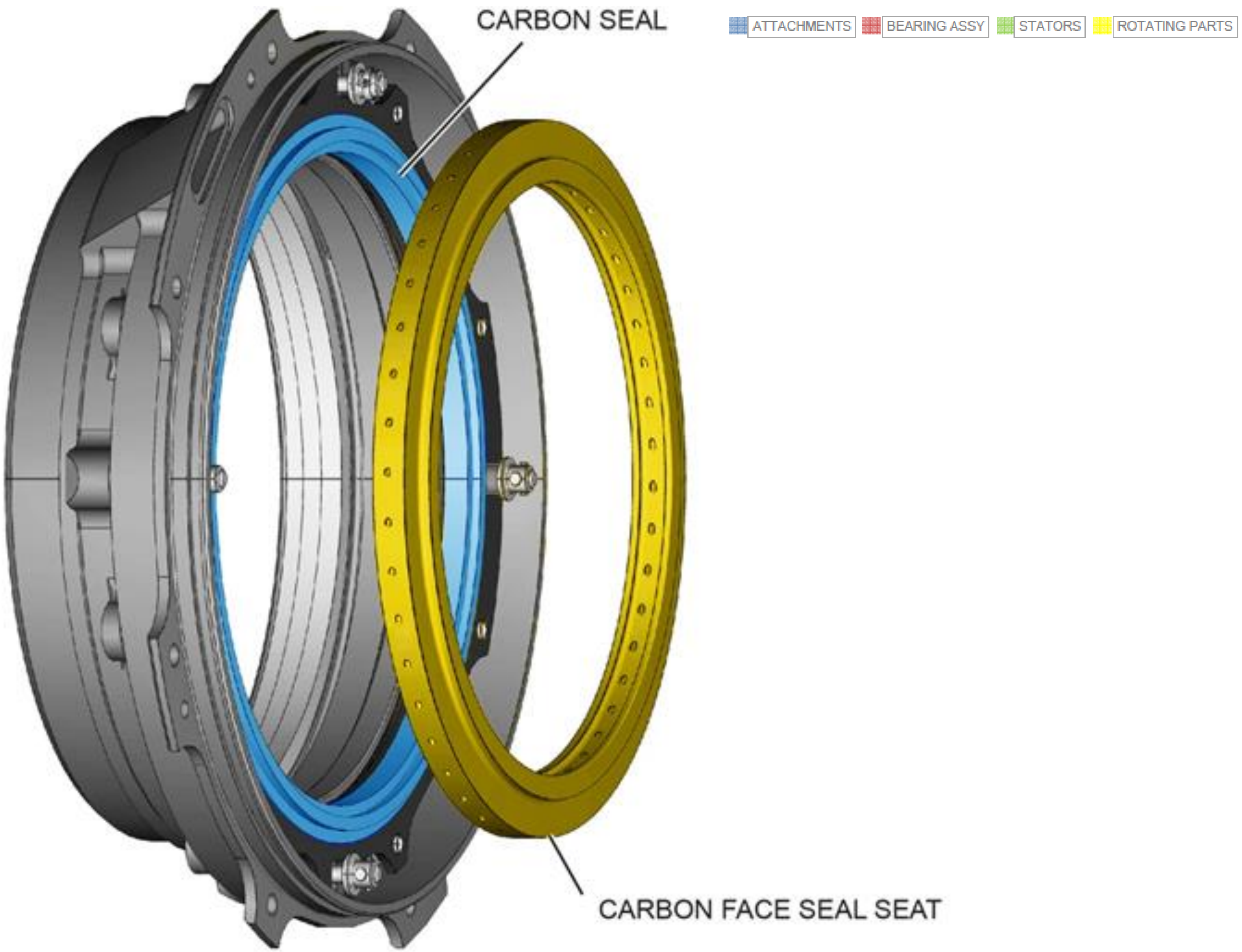
Carbon face seals seat axially against a rotating ring.

Some carbon face seals are called *lift-off* seals because extra air is used to physically lift the seal off the ring during engine operation.

Bearings and their seal types are shown at right.

Each compartment has a scupper that returns any start-up leakage oil.

Bearing No.	Seal Type
1, 1.5, 2, 4, 5, 6	Face
3	Lift-off


CARBON SEAL
ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
CARBON FACE SEAL SEAT

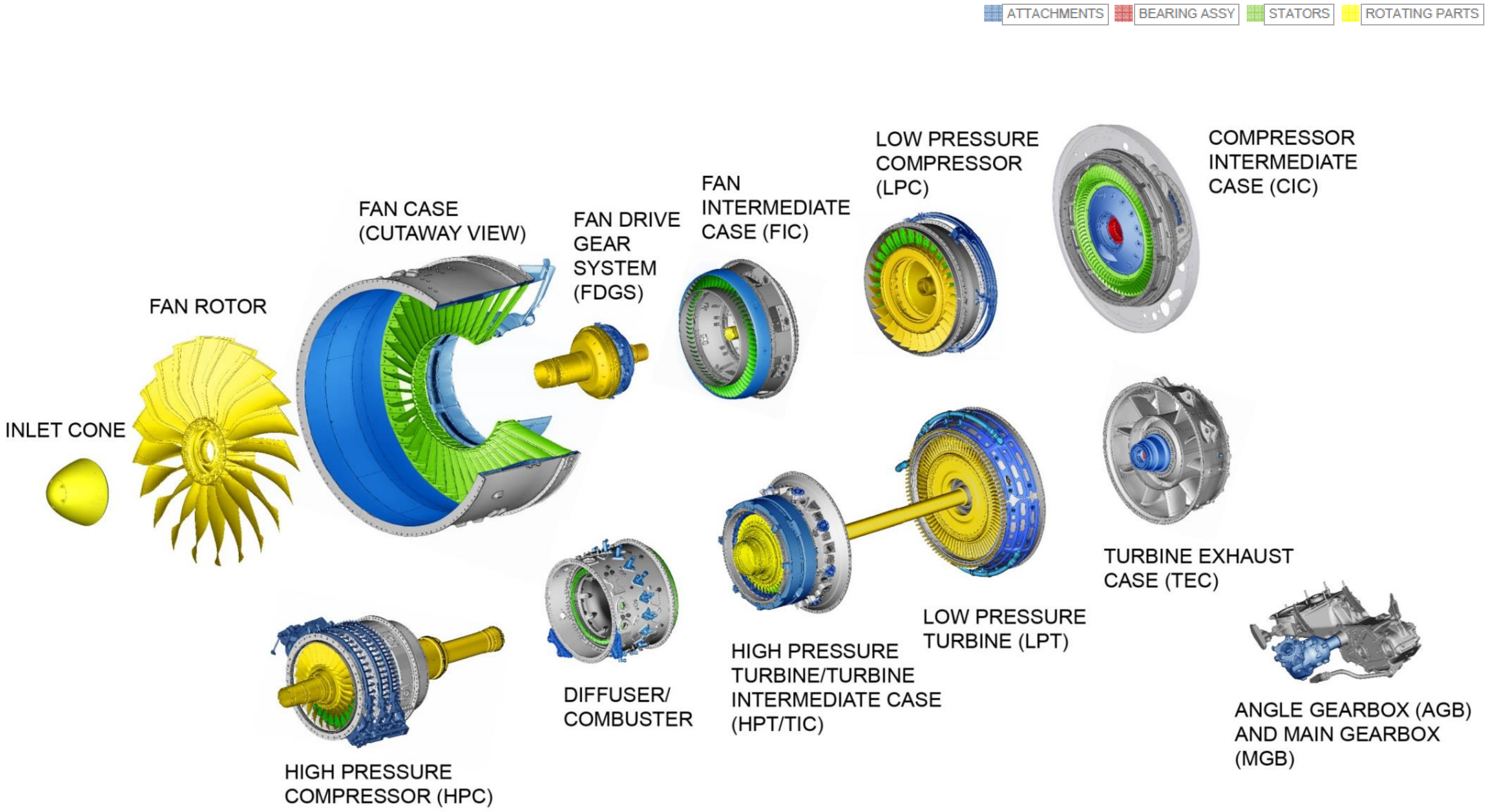
ENGINE MODULES

A module is the largest assembly of engine parts that can be treated in one of two ways:

- removed or installed from the engine as a unit
- disassembled or preassembled, independently of other modules.

PW1100G-JM assembly modules are as follows.

- Fan rotor (including inlet cone)
- Fan case
- Fan Drive Gear System FDGS
- Fan Intermediate Case FIC
- Low Pressure Compressor LPC
- Compressor Intermediate Case CIC
- High Pressure Compressor HPC
- Diffuser/Combustor/ High Pressure Turbine nozzle
- High Pressure Turbine HPT
- Turbine Intermediate Case TIC
- Low Pressure Turbine LPT
- Turbine Exhaust Case TEC
- Angle Gearbox AGB
- Main Gearbox MGB


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
LOW PRESSURE COMPRESSOR (LPC)
COMPRESSOR INTERMEDIATE CASE (CIC)
FAN INTERMEDIATE CASE (FIC)
FAN CASE (CUTAWAY VIEW)
FAN DRIVE GEAR SYSTEM (FDGS)
FAN ROTOR
INLET CONE
TURBINE EXHAUST CASE (TEC)
LOW PRESSURE TURBINE (LPT)
HIGH PRESSURE TURBINE/TURBINE INTERMEDIATE CASE (HPT/TIC)
DIFFUSER/ COMBUSTER
ANGLE GEARBOX (AGB) AND MAIN GEARBOX (MGB)
HIGH PRESSURE COMPRESSOR (HPC)

FAN ROTOR

Purpose:

The fan rotor draws in ambient air and provides the first of 12 stages of compression necessary to yield more than 90% of the thrust produced by the engine.

Location:

The fan rotor is located at the front of the engine.

The inlet cone and cover are at the front of the fan rotor.

Description:

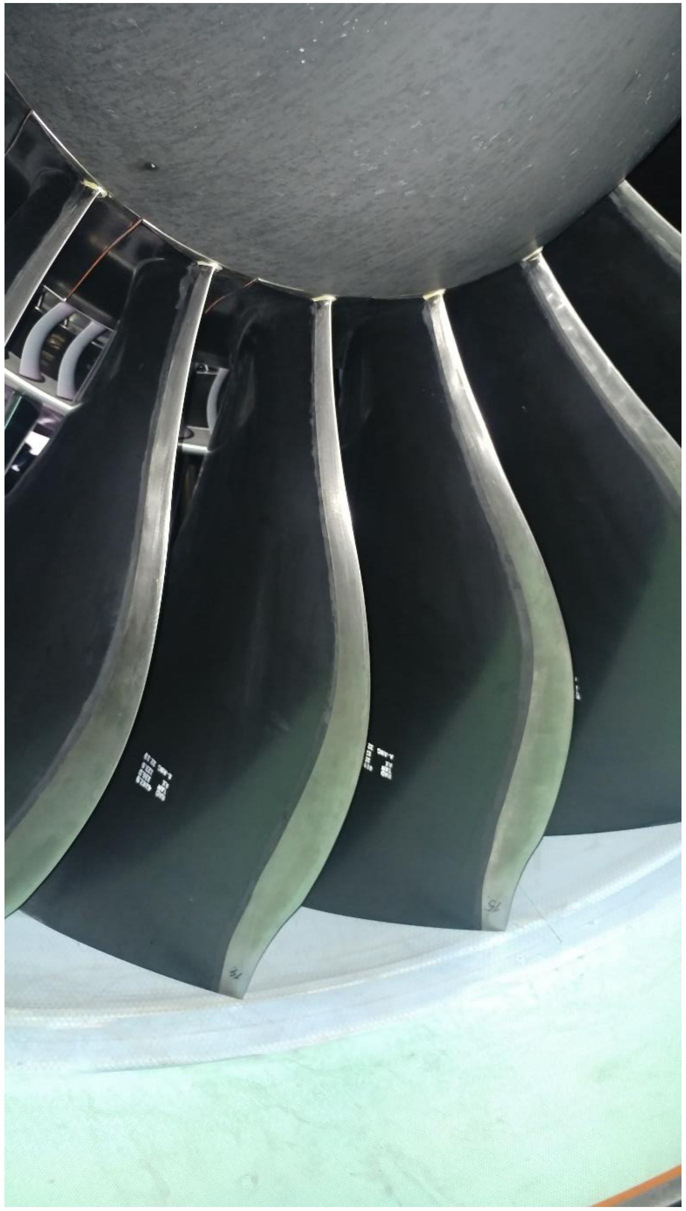
The fan rotor includes the inlet cone and 20 fan blades with integrated fairings and reinforced leading edges.

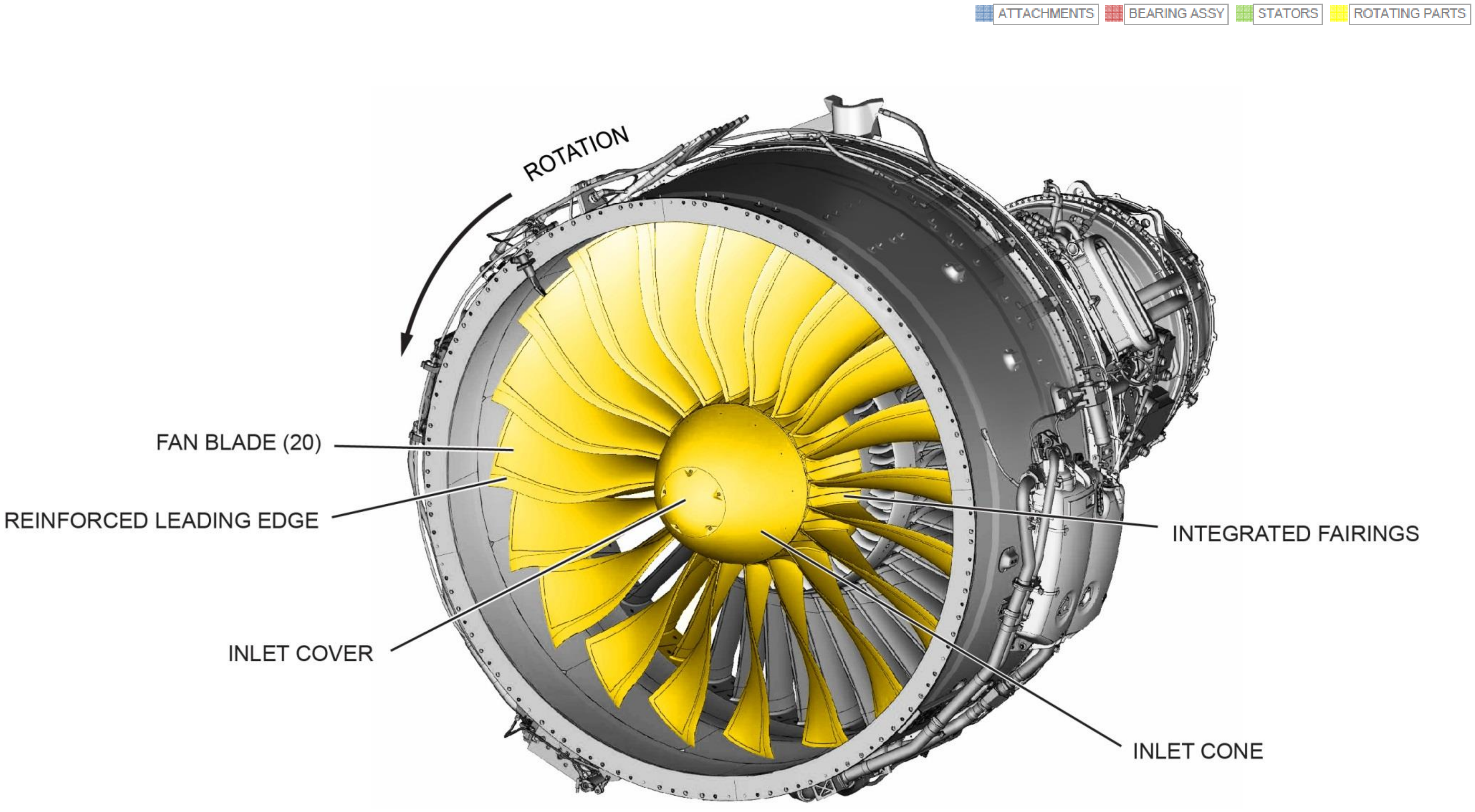
Fan diameter is 81 inches.

The fan rotor is supported by bearing nos. 1 and 1.5, which are tapered roller bearings.

The fan rotates in a clockwise direction as viewed from the aft end of the engine looking forward.

The fan is connected to the fan drive shaft. Power to turn the fan is supplied by the fan drive gear through the fan drive shaft.




ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
ROTATION
FAN BLADE (20)
REINFORCED LEADING EDGE
INLET COVER
INTEGRATED FAIRINGS
INLET CONE

INLET CONE

Purpose:

At the front of the rotor, the inlet cone and its cover smooth the flow of air to the engine.

Location:

The inlet cone is attached to the fan hub.

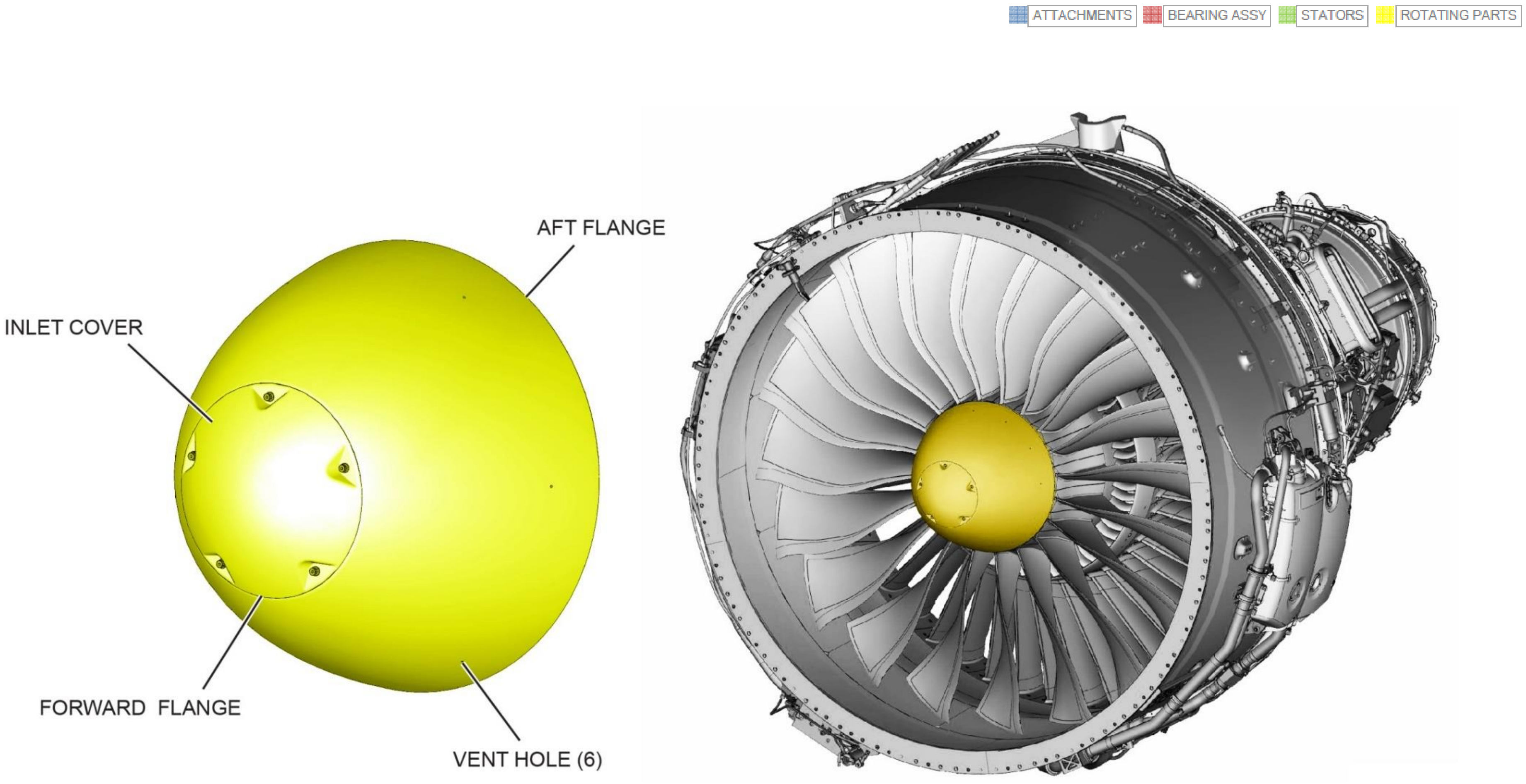
Description:

The inlet cone is made of composite material. Its front flange provides attachment for the inlet cone cover.

The inlet cone's rear flange is bolted to the fan hub and is part of the fan blade retention system.

The inlet cone is anti-iced with a continuous flow of 2.5 bleed air.

The cone has holes around its circumference for venting anti-ice air.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
AFT FLANGE
INLET COVER
FORWARD FLANGE
VENT HOLE (6)

FAN BLADE

Purpose:

Fan blades accelerate the air entering the engine, producing most thrust and providing airflow to the primary gas path to be used for combustion and cooling.

Location:

Fan blades are located on the fan hub.

Description:

The 20 fan blades are partially hollow and made of aluminium, with a dovetail root to engage slots in the fan hub. Composite Teflon wear strips are bonded to the pressure surfaces of each fan blade dovetail to prevent wear on the blade root pressure surfaces and to reduce fan rotor vibration.

Axial retention of the blades is provided by front and rear lock rings. Composite fan blade spacers are installed beneath the fan blades to provide a radial preload of the blades, which also reduces fan rotor vibration.

The spacers are mechanically trapped by the front and rear lock rings.

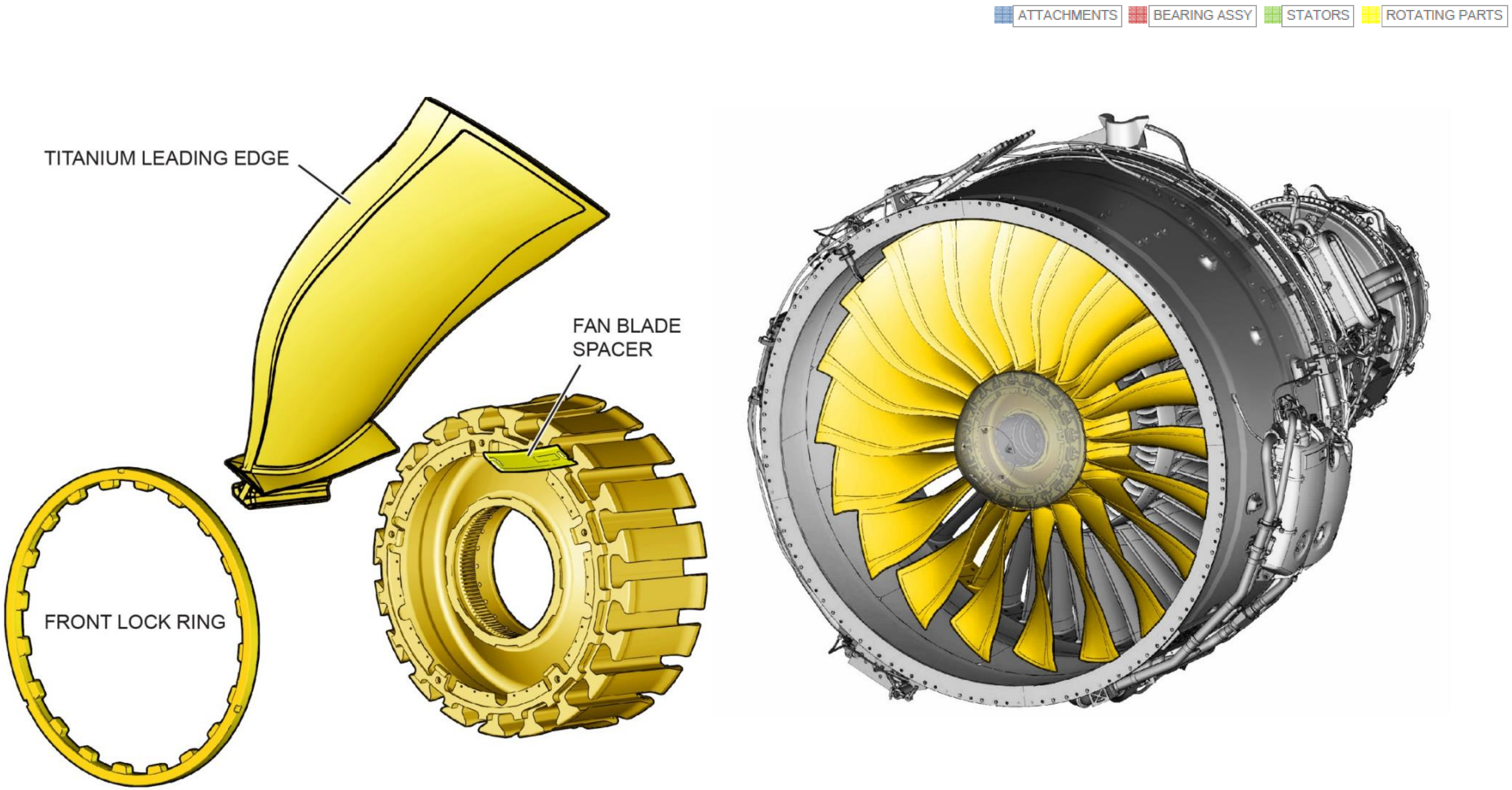
An erosion coating is applied on the aerofoil and a titanium strip is bonded to the leading edge of each blade to reduce leading edge erosion

Safety Conditions

WARNING

USE PROTECTIVE GLOVES TO PREVENT POSSIBLE INJURY TO THE HANDS WHEN YOU HOLD THE FAN BLADES.

THE BLADE EDGES ARE SHARP AND CAN CUT THE HANDS.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
TITANIUM LEADING EDGE
FAN BLADE
SPACER
FRONT LOCK RING

The blades are a hollow aluminium design that has a dovetail root that engages slots in the fan hub.

The blade design (which includes a reinforced leading edge) decreases impact damage (bird strike or Foreign Object Damage (FOD)) and noise.

No mid-span or part-span shrouds are necessary.

Front and rear lock rings hold the fan blades in their correct axial position in the hub.

Composite under-root spacers beneath the fan blades provide a radial preload of the blades to reduce fan rotor vibration.

It is possible to replace fan blades in an assembled engine and in a fan rotor removed from the engine.

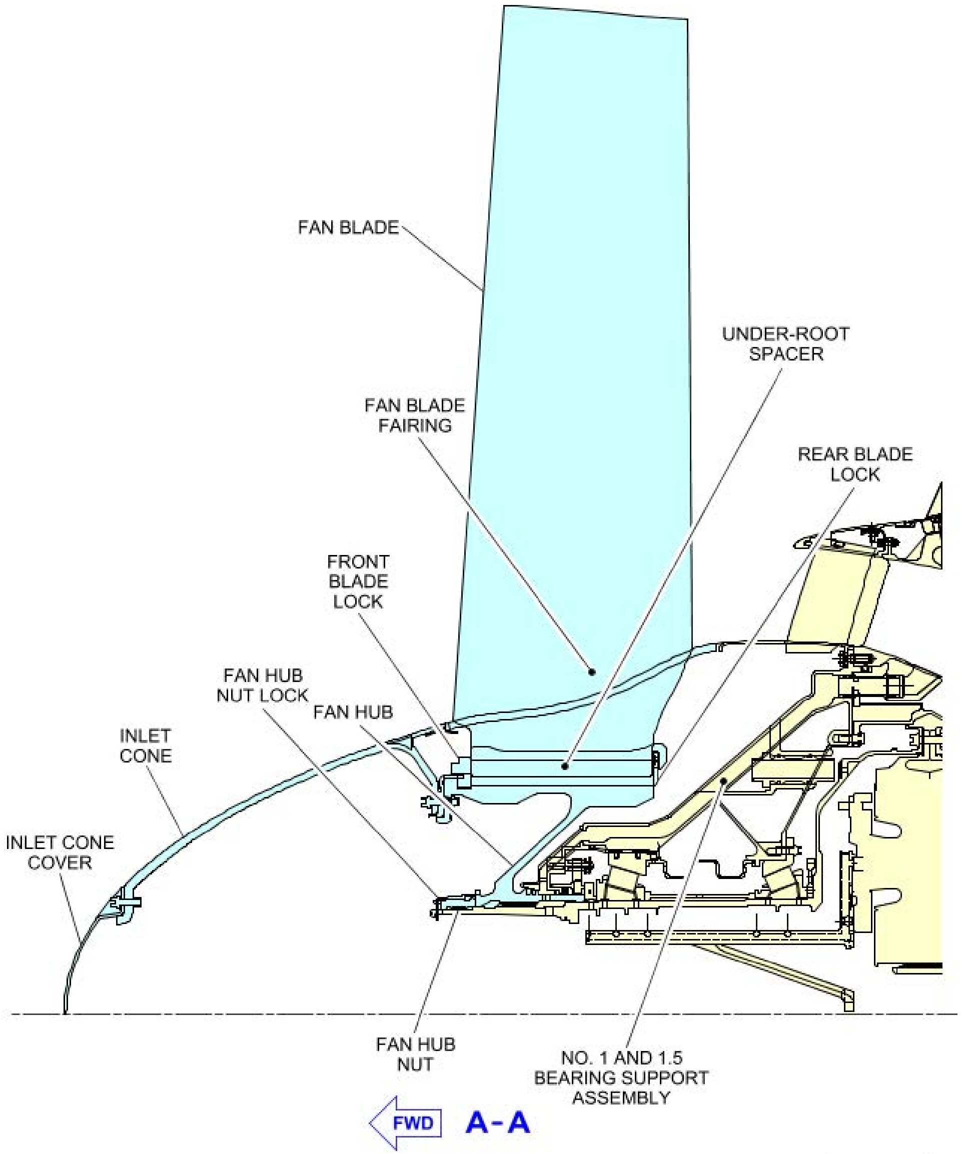
Counterweights can be added to the outer rim of the fan hub when necessary.

The fan is driven by the LPC/LPT through the Fan Drive Gear System (FDGS), a gear reduction unit which decreases the fan speed.

Because the fan speed is lower than that of the LPC/LPT, there is increased efficiency across the full engine operating range.

At the front of the fan rotor is the inlet cone and the inlet cone cover.

These parts are made of composite material and keep the flow of air into the engine smooth.


FAN BLADE
UNDER-ROOT SPACER
FAN BLADE FAIRING
REAR BLADE LOCK
FRONT BLADE LOCK
FAN HUB NUT LOCK
FAN HUB
INLET CONE
INLET CONE COVER
FAN HUB NUT
NO. 1 AND 1.5 BEARING SUPPORT ASSEMBLY
FWD
A-A

FAN CASE ASSEMBLY

Purpose:

The Fan Case Assembly contains and directs the fan airstream, sending part of the air directly through the gas path and the majority of air outside the gas path as bypass air.

The fan case also provides the structural link between the inlet cowl and the core engine.

In case of 1st Stage fan blade failure, the fan case will contain the liberated blade.

Location:

The Fan Case Assembly is located between the inlet cowl and the Fan Intermediate Case (FIC).

Description:

The Fan Case Assembly is made up of the fan case, Fan Exit Guide Vanes (FEGVs), fan exit liner segments and fan exit fairing and support.

The fan case is a one-piece, composite case with an acoustically treated inner surface that decreases noise.

A fan blade rub strip area protects fan blades from contact with the fan case.

An ice liner protects the case against ice shed by fan blades.

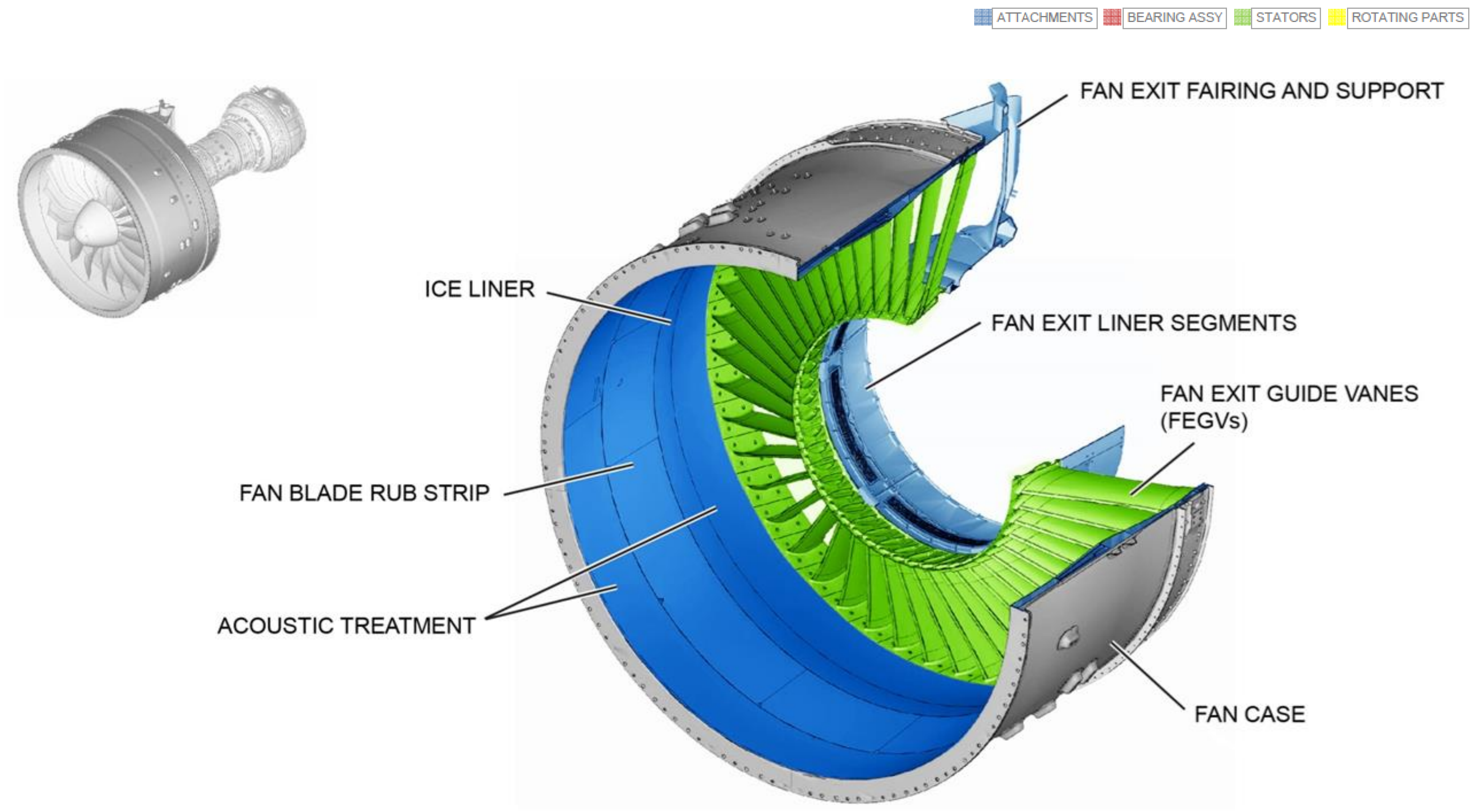
An aluminium support ring at the top rear of the fan case has a V-groove that provides alignment and support for the thrust reverser doors.

On the inner surface of the fan case, 48 hollow aluminium composite Fan Exit Guide Vanes extend to the Fan Intermediate Case.

The stationary FEGVs straighten the fan air and also provide radial support between the FIC and the Fan Case Assembly.

A fan exit liner assembly goes around the outer area of the LPC.

Louvers in these fan exit liner segments release 2.5 bleed air from the Low-Pressure Compressor into the fan stream at the correct angle.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
FAN EXIT FAIRING AND SUPPORT
ICE LINER
FAN EXIT LINER SEGMENTS
FAN EXIT GUIDE VANES (FEGVs)
FAN BLADE RUB STRIP
ACOUSTIC TREATMENT
FAN CASE

FAN EXIT GUIDE VANES

Purpose:

The Fan Exit Guide Vanes (FEGVs) straighten and direct the fan discharge airstream.

They supply structural support of flight and blade-out loads and also provide radial support of the engine.

Location:

The Fan Exit Guide Vanes are located aft of the fan blades.

Description:

A total of 48 hollow aluminium composite FEGVs extend diagonally rearward from the outer diameter of the Fan Intermediate Case to the inner diameter of the fan containment case.

The aluminium composite material was chosen for its strength and weight savings.

The FEGVs straighten fan bypass air and provide radial support for the Fan Case Assembly.

A titanium strip is bonded to the leading edge of each FEGV to protect against erosion.

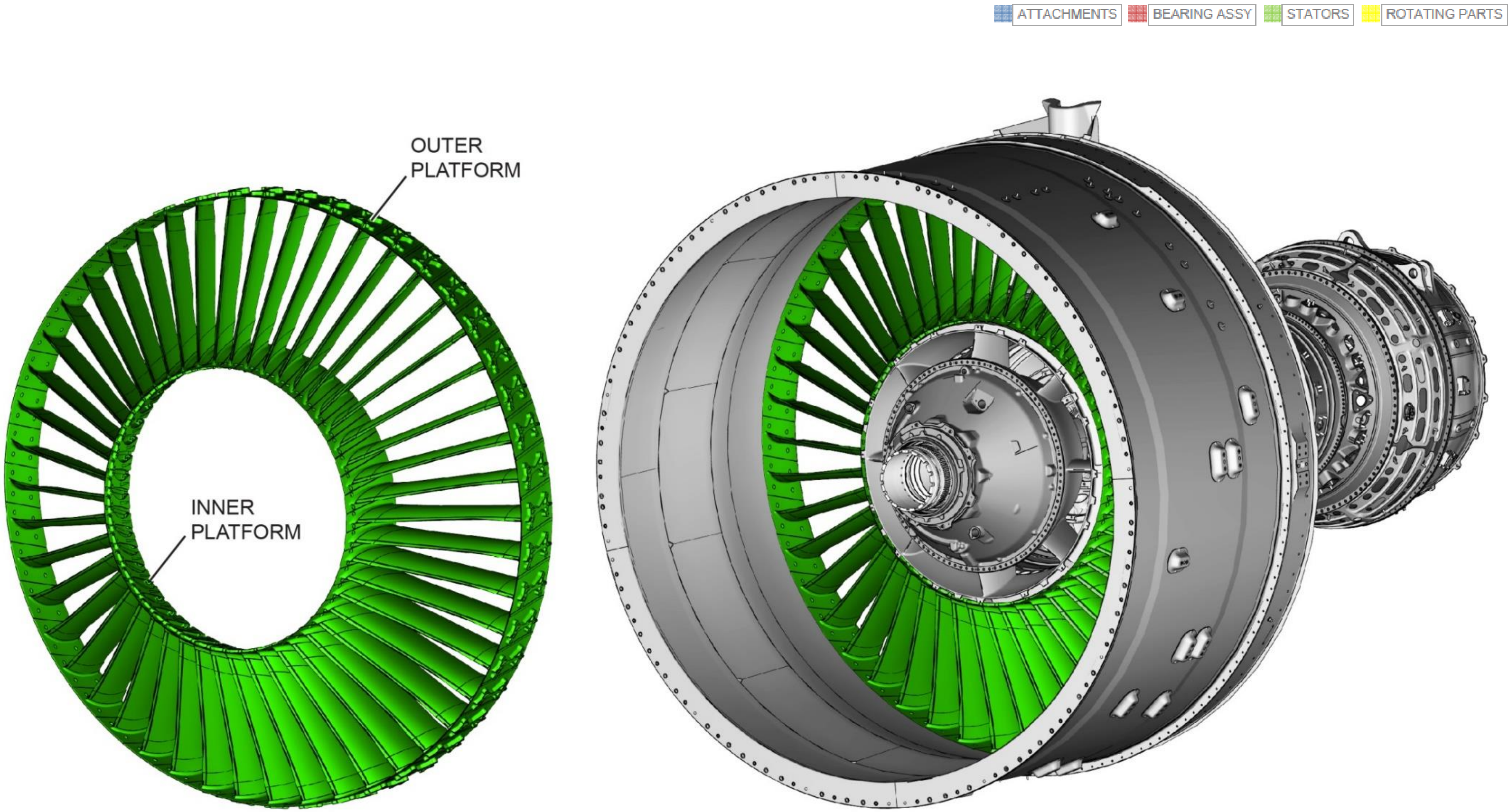
Each FEGV is attached to the Fan Intermediate Case along the inner platform and to the fan containment case at the outer platform.

Safety Conditions

WARNING

REMOVE AND INSTALL ONLY ONE FAN EXIT GUIDE VANE AT A TIME. FAN EXIT GUIDE VANES ARE NECESSARY FOR ENGINE STRUCTURE.

IF YOU DO NOT OBEY THIS WARNING, INJURY CAN OCCUR.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
OUTER PLATFORM
INNER PLATFORM

FAN DRIVE GEAR SYSTEM (FDGS)

Purpose:

The Fan Drive Gear System allows the fan and low spool (LPC/LPT) to operate at different speeds, improving performance and efficiency, respectively.

Location:

The FDGS is located between the fan rotor and the Low-Pressure Compressor (LPC) and is attached to the Fan Intermediate Case.

Description:

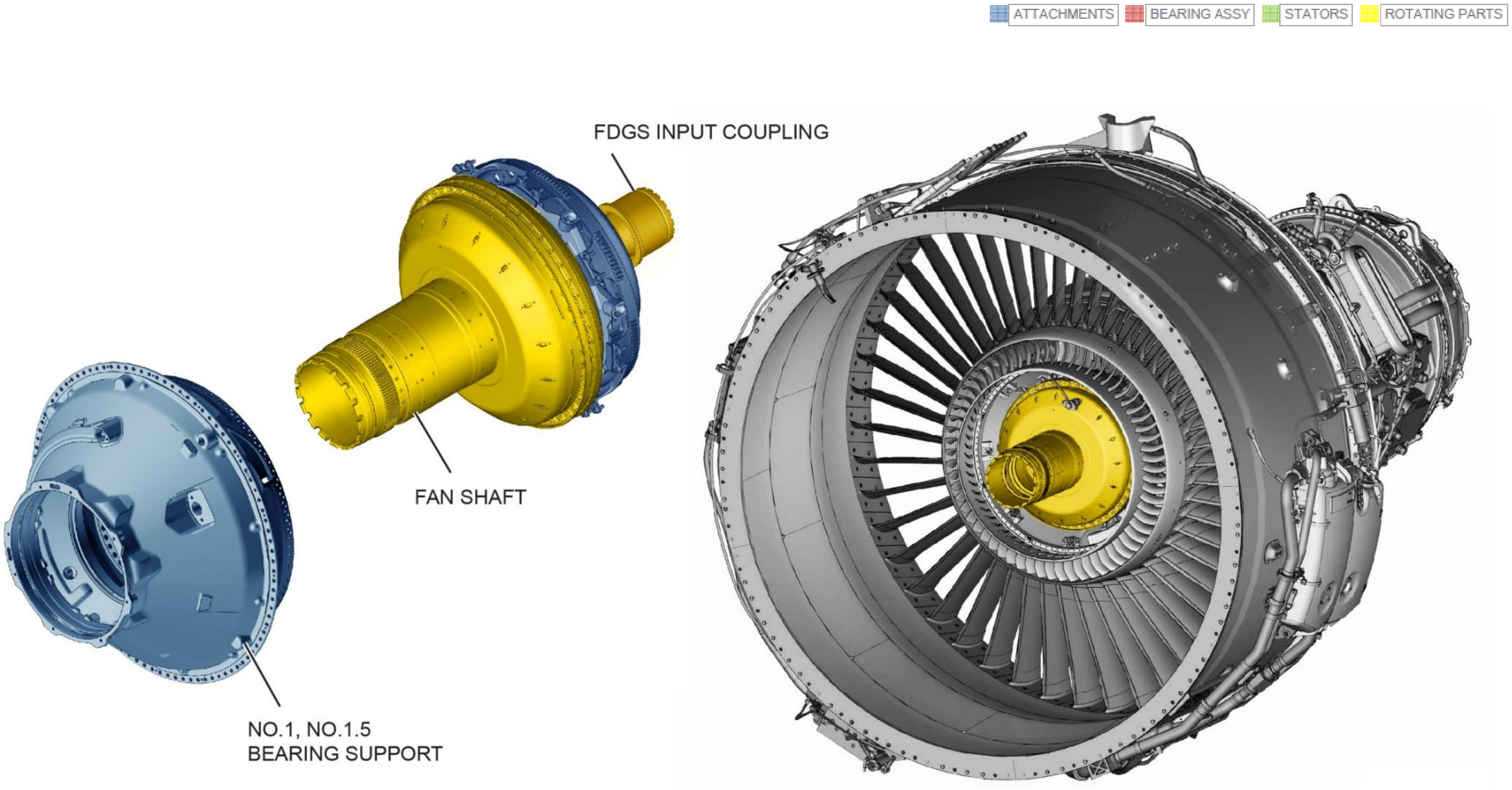
The FDGS is made up of a central sun gear surrounded by five star gears which are supported by journal bearings and an outer ring gear.

A torque frame and flex mount helps with alignment of the FDGS input coupling and with fan alignment to the fan drive gear, also reducing extreme loads that can be transferred to the FDGS from the fan and LPC rotors, such as at take-off.

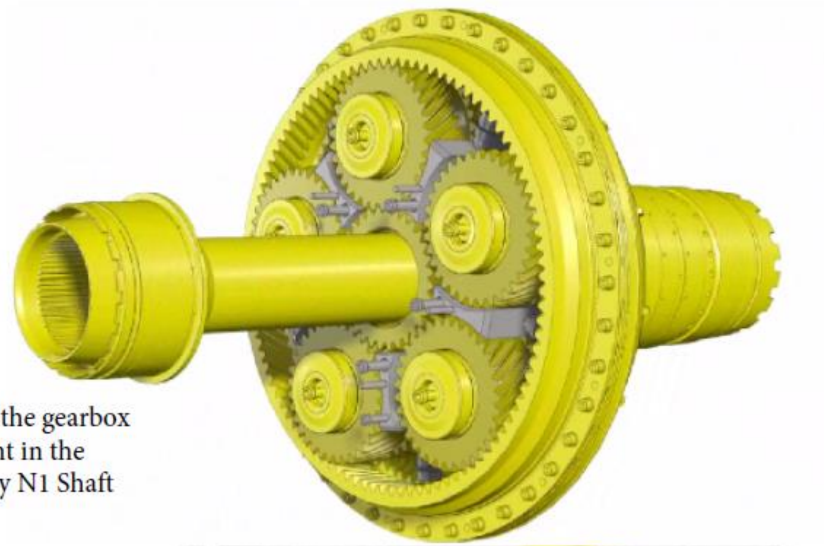
The front of the FDGS is supported by bearings nos. 1 and 1.5.

The FDGS has an auxiliary oil supply to lubricate the journal bearings during a negative g-force or windmill event that would affect normal oil flow.

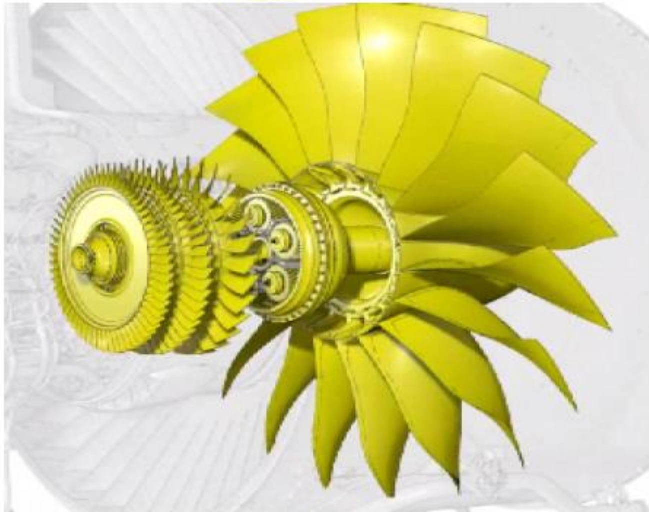
The auxiliary system uses a windmill/auxiliary pump during these conditions.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
FDGS INPUT COUPLING
FAN SHAFT
NO.1, NO.1.5
BEARING SUPPORT

INTENTIONALLY BLANK



Diagrams Show the gearbox and its placement in the engine, driven by N1 Shaft



Operation:

A conventional engine runs the fan and turbine at one speed.

The PW1100G-JM allows these components to run at independent speeds. To make this happen, the FDGS sends energy from the N1 rotor through a system of gears, slowing output to the fan.

The process alters the normal 1:1 turning ratio to 3:1, or three turns of the N1 rotor for a single revolution of the fan.

1. The fan drive gear is a star gear reduction unit that takes the torque from the low spool (LPC/LPT), and through the input coupling uses it to turn a sun gear.

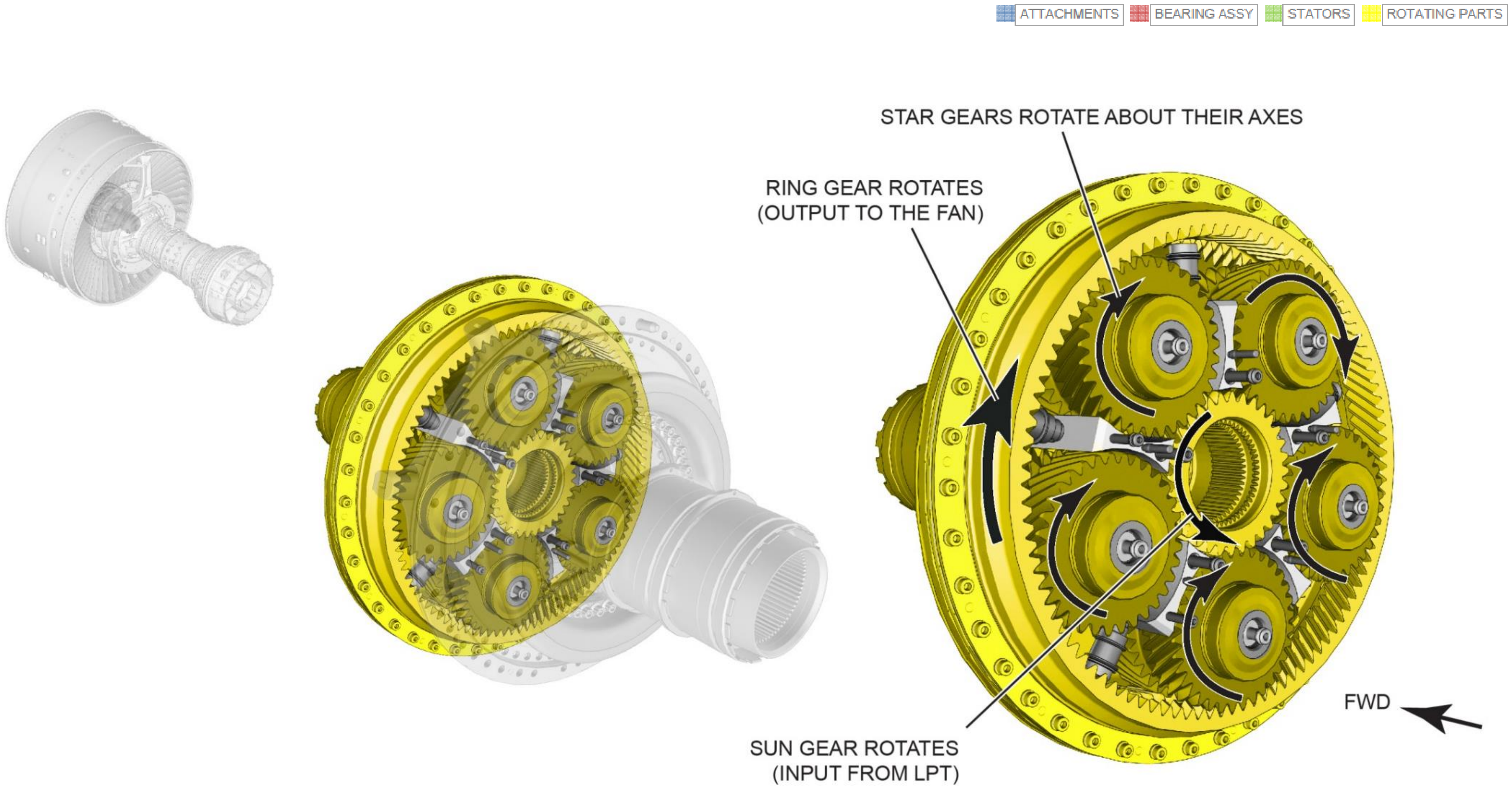
2. The sun gear then turns the five star gears against the outer ring gear, which is connected to the fan hub of the fan shaft.

The ratio of LPC to fan hub speed is approximately 3:1.

3. The star gears and the carrier to which they are attached do not move around the sun gear.

The sun gear engages the star gears, moving them in a direction that causes the outer ring gear and fan to turn in the opposite direction from the sun gear and LPC/LPT, at a slower speed.

This design allows for lower fan speeds and higher LPC/LPT speed, increasing compressor efficiency.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
STAR GEARS ROTATE ABOUT THEIR AXES
RING GEAR ROTATES
(OUTPUT TO THE FAN)
SUN GEAR ROTATES
(INPUT FROM LPT)
FWD

FAN INTERMEDIATE CASE (FIC)

Purpose:

The Fan Intermediate Case module provides support for bearing nos. 1 and 1.5, and for the Fan Drive Gear System.

The FIC supports and contains the No. 2 Bearing assembly located behind it and also supports the fan case.

Location:

The FIC is located between the fan rotor and the Low-Pressure Compressor.

Description:

The FIC is made up of the fan exit stator and fairing, the No. 2 Bearing seal/support assembly, the FDGS input coupling, and one set of LPC Variable Inlet Guide Vanes (VIGVs).

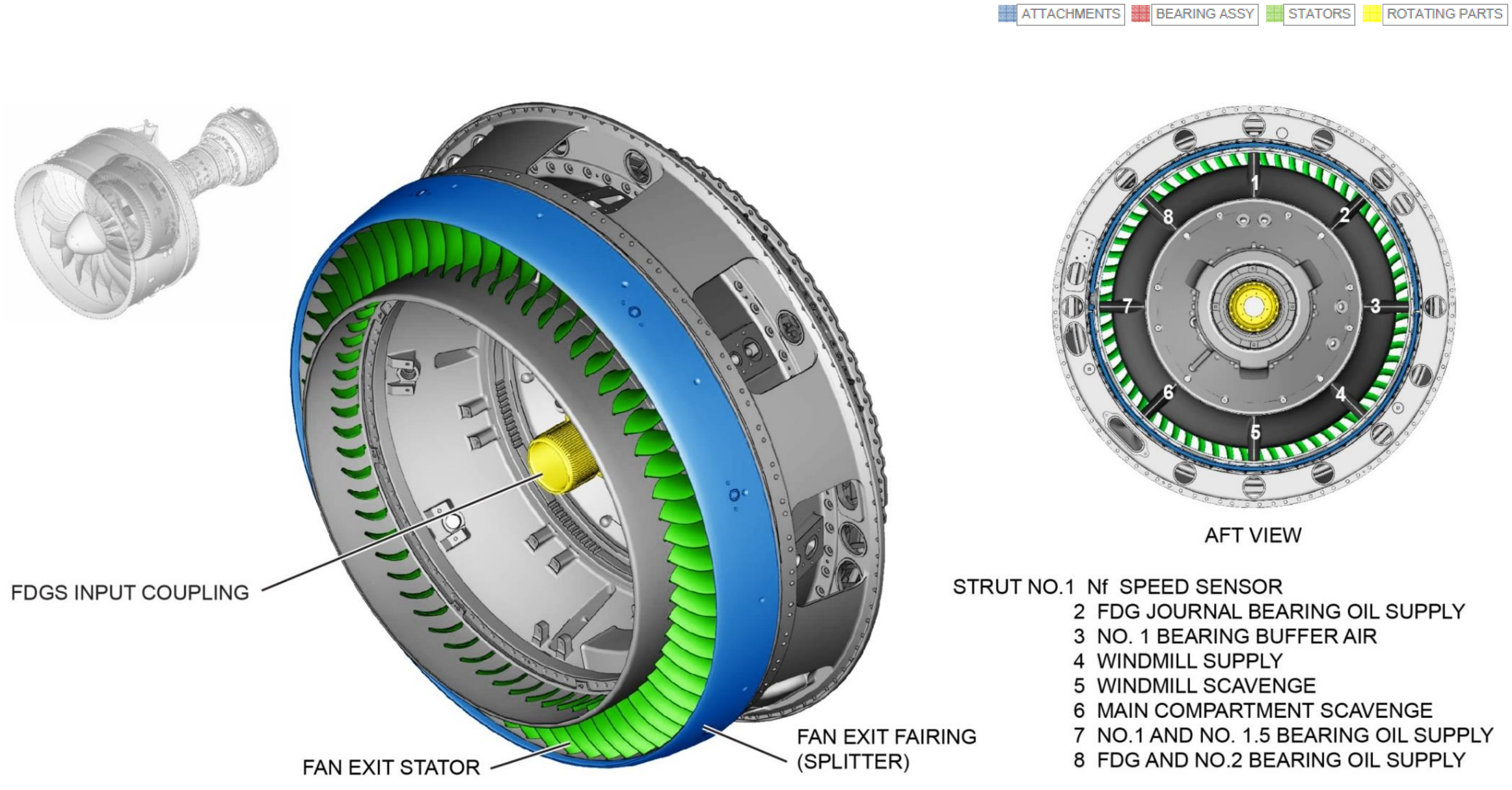
The VIGVs direct fan airflow into the Low-Pressure Compressor at the correct angle.

A fan exit fairing smooths the airflow into and around the fan exit stator.

The EEC can adjust the VIGVs for varying engine operating conditions.

The No. 2 Bearing is a ball bearing that holds the LPC rotor axially and radially. The bearing is oil-damped.

Eight FIC struts provide structural support and pathways for oil supply, oil scavenge, and buffer air to the FDGS and bearing nos. 1, 1.5 and 2.



STRUT NO.1 Nf SPEED SENSOR
2 FDG JOURNAL BEARING OIL SUPPLY
3 NO. 1 BEARING BUFFER AIR
4 WINDMILL SUPPLY
5 WINDMILL SCAVENGE
6 MAIN COMPARTMENT SCAVENGE
7 NO.1 AND NO. 1.5 BEARING OIL SUPPLY
8 FDG AND NO.2 BEARING OIL SUPPLY

LOW PRESSURE COMPRESSOR

Purpose:

The Low-Pressure Compressor increases the pressure of gas path air from the fan and sends it to the Compressor Intermediate Case and the High-Pressure Compressor.

Location:

The LPC is located to the rear of the Fan Intermediate Case.

Description:

The LPC is connected at its front to the fan rotor through the Fan Drive Gear System (FDGS).

The LPC is made up of three Integrally Bladed Rotors and two stator stages.

The third stage stator is part of the Compressor Intermediate Case Assembly.

Tie rods attach the LPC rotor hub to the 1st, 2nd and 3rd stage rotors.

The LPT shaft splines into the LPC rotor hub, and the No. 2 Bearing supports the LPC and the front of the LPT shaft.

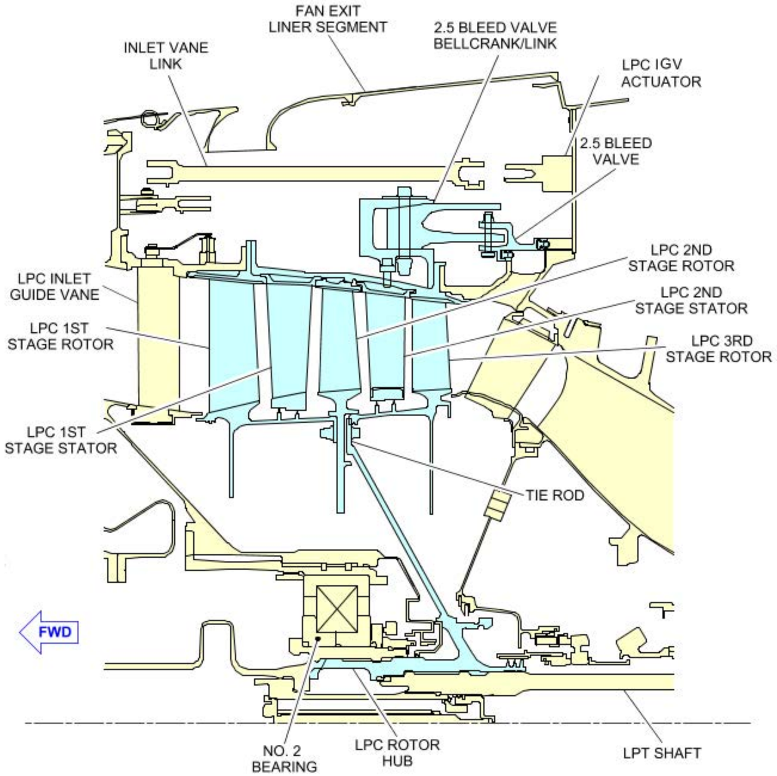
An annular 2.5 bleed valve at the rear of the LPC is controlled by an actuator, rod, and bellcrank linkage. The bleed valve releases air from the LPC, enhancing stability.

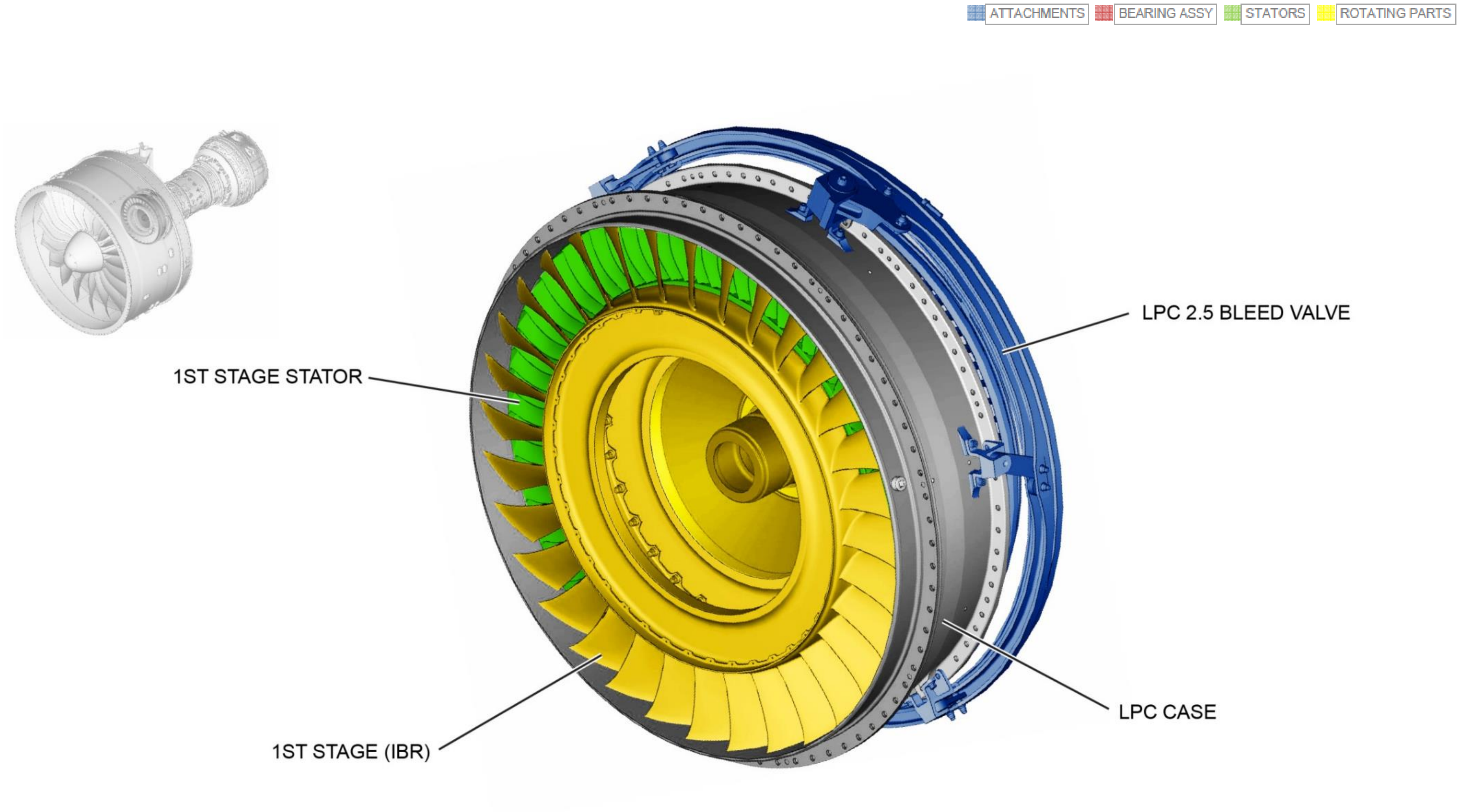
Access ports for LPC borescope inspection are found at 3:30, 4:00 and 9:30, viewed from the aft end of the engine looking forward.

Note that the port at 3:30 is located on the FIC case.

Air from the rear of the Fan Intermediate Case goes through the LPC Stator Vane Assembly Variable Inlet Guide Vanes and into the three-stage compressor.

The LPC rotates in a counter clockwise direction as seen from the rear.




ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
LPC 2.5 BLEED VALVE
1ST STAGE STATOR
LPC CASE
1ST STAGE (IBR)

COMPRESSOR INTERMEDIATE CASE (CIC)

Purpose:

The Compressor Intermediate Case contains and provides a flow path for engine core airflow coming from the LPC to the HPC.

In addition, it supports the No. 3 Bearing/bevel gear shaft and the gearbox drive bevel gear assemblies.

Location:

The CIC is the transition case between the low pressure and high compressors.

Description:

The CIC contains two primary engine mounts, a redundant engine mount, and two thrust link mounts.

The CIC is bounded by the LPC exit stator at the front and by the HPC inlet variable guide vane assembly at the rear.

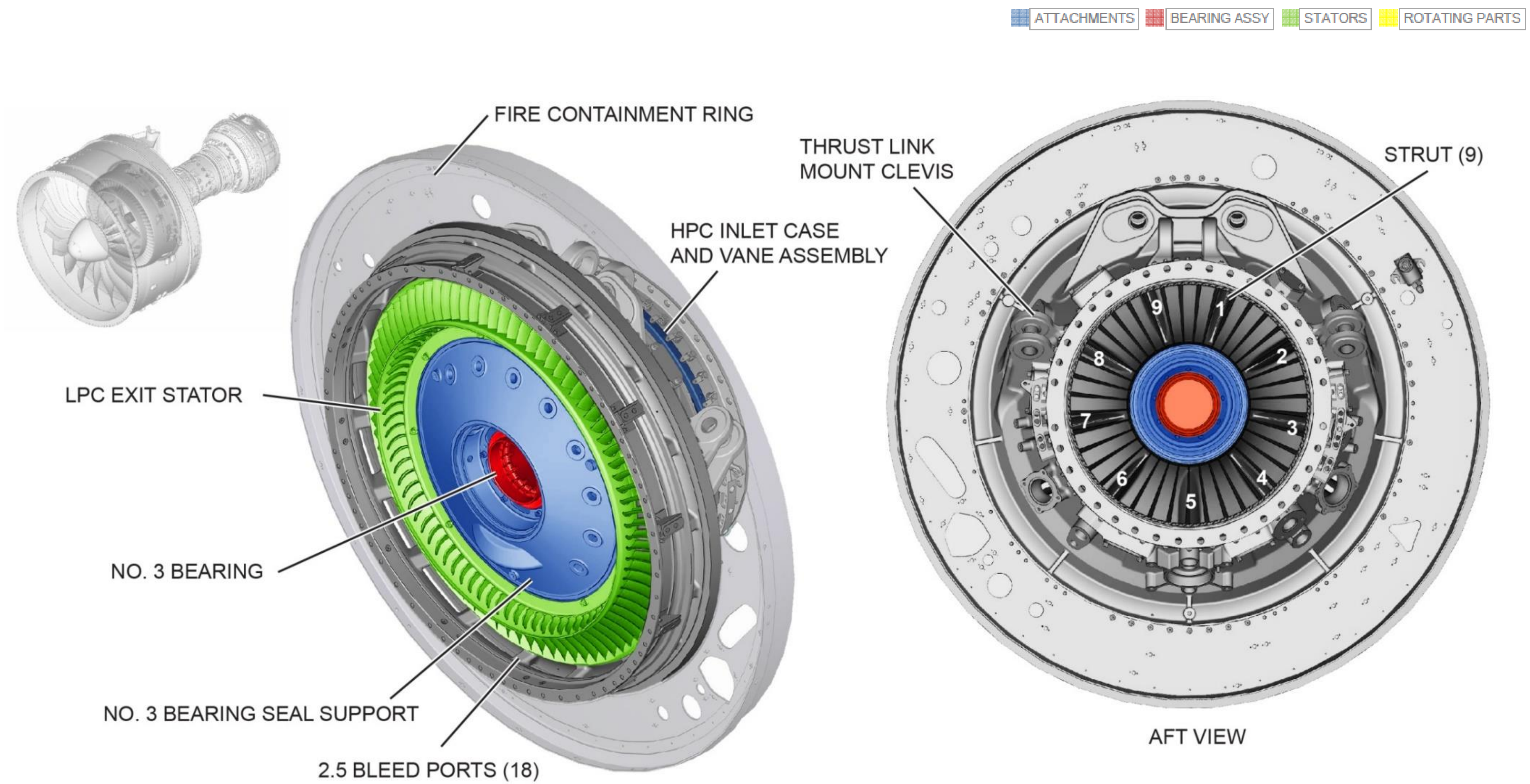
Ports for 2.5 bleed air are located at the front of the CIC.

The CIC contains No. 3 Bearing seals and the oil pressure and oil scavenge tubes that are routed through the case struts.

Case struts are also used to route buffer supply air to bearing nos. 2 and 3, and to route breather air from the No. 3 Bearing and the tower shaft that drives the Angle Gearbox.

On the aft side of the CIC, two thrust link mount clevises and a fire containment ring separate the core nacelle from the LPC.
The ring also supports the thrust reverser Inner Fixed Structure.

Strut	Pathway
1	N/A
2	Forward buffer supply
3	Rear buffer supply/N1 sensor
4	Rear buffer supply
5	• Tower shaft • No. 3 Bearing compartment oil scavenge
6	No. 3 Bearing dampener oil supply
7	No. 3 Bearing main oil supply
8	Compartment breather vent
9	N/A

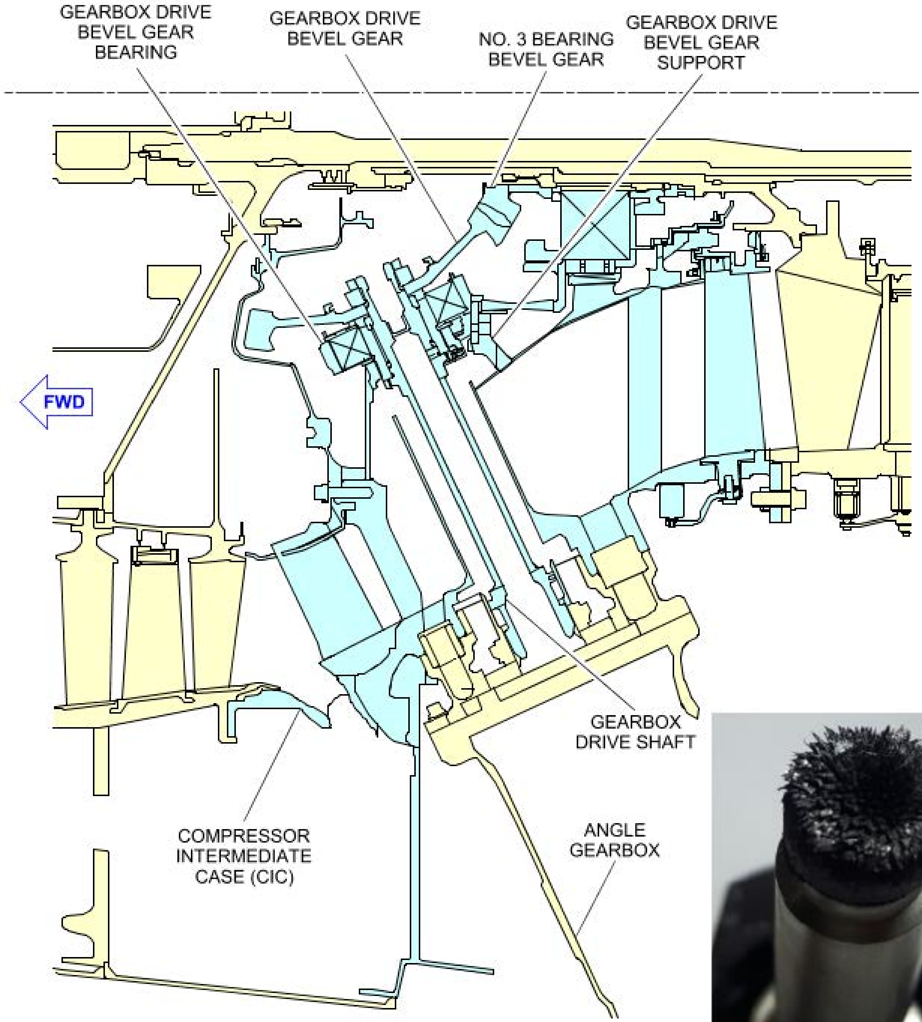

ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
FIRE CONTAINMENT RING
THRUST LINK
MOUNT CLEVIS
STRUT (9)
HPC INLET CASE
AND VANE ASSEMBLY
LPC EXIT STATOR
NO. 3 BEARING
NO. 3 BEARING SEAL SUPPORT
2.5 BLEED PORTS (18)
1
2
3
4
5
6
7
8
9
AFT VIEW

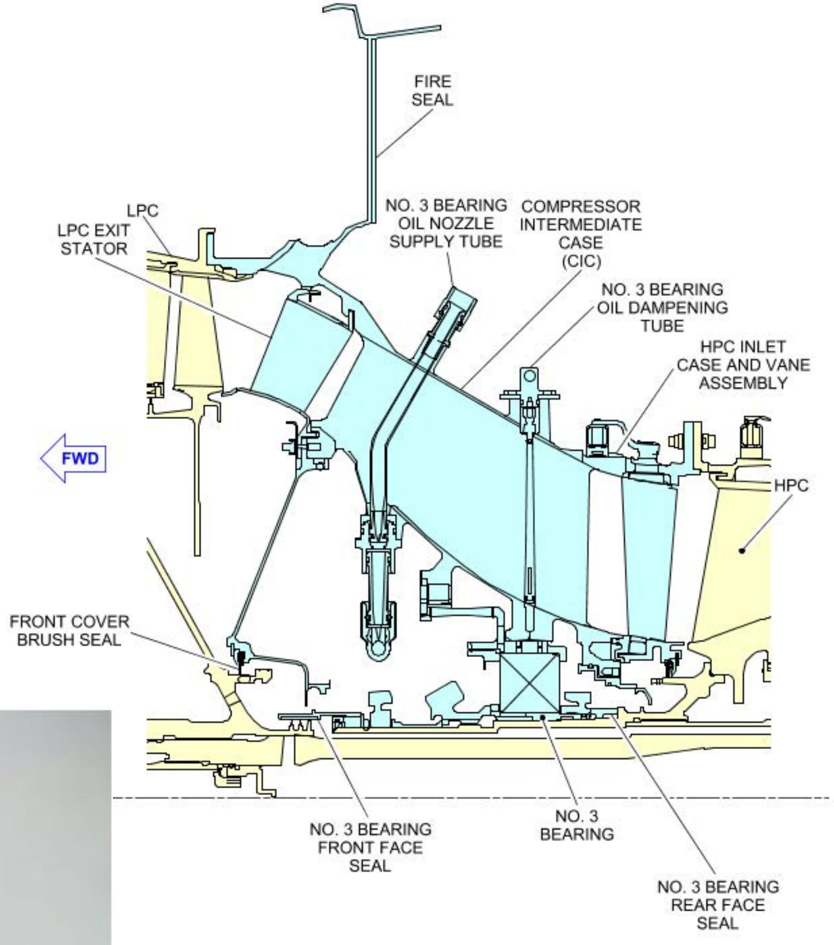
No.3 BEARING/BEVEL GEAR SHAFT & GEARBOX DRIVE BEVEL GEAR ASSY

NOTE: The No. 3 bearing front and rear face seals are wet-face carbon seals of a lift-off configuration.

Grooves in the faces of the sealing seats push away the carbon seals at high speed, with decreased friction and wear and no increased leakage.

Bearing 3 needs to be very closely monitored as this example shows particles here may well be a No-Go


GEARBOX DRIVE BEVEL GEAR BEARING
GEARBOX DRIVE BEVEL GEAR
NO. 3 BEARING BEVEL GEAR
GEARBOX DRIVE BEVEL GEAR SUPPORT
FWD
GEARBOX DRIVE SHAFT
COMPRESSOR INTERMEDIATE CASE (CIC)
ANGLE GEARBOX


FIRE SEAL
LPC
LPC EXIT STATOR
NO. 3 BEARING OIL NOZZLE SUPPLY TUBE
COMPRESSOR INTERMEDIATE CASE (CIC)
NO. 3 BEARING OIL DAMPENING TUBE
HPC INLET CASE AND VANE ASSEMBLY
FWD
HPC
FRONT COVER BRUSH SEAL
NO. 3 BEARING FRONT FACE SEAL
NO. 3 BEARING
NO. 3 BEARING REAR FACE SEAL

HIGH PRESSURE COMPRESSOR

Purpose:

The High-Pressure Compressor increases the speed and pressure of primary gas path air before sending it to the diffuser and combustor.

Location:

The HPC is located between the CIC and the diffuser and combustor.

Description:

The HPC has eight stages, in contrast to traditional turbofan engine technology that requires 10 to 17 stages.

The lower count is due to efficiencies produced by the FDGS. The eight rotor stages are composed of Integrally Bladed Rotors (IBRs).

Rotor stages are held together with a tie shaft that connects the HPC front hub and rear hub, and extends rearward to the High-Pressure Turbine.

The HPC is held radially and axially at the front by the No. 3 Bearing, which is a ball bearing, and is held radially at the rear by the No. 4 Bearing, which is a roller bearing.

Both bearings are oil damped to reduce wear and to reduce HPC rotor vibration.

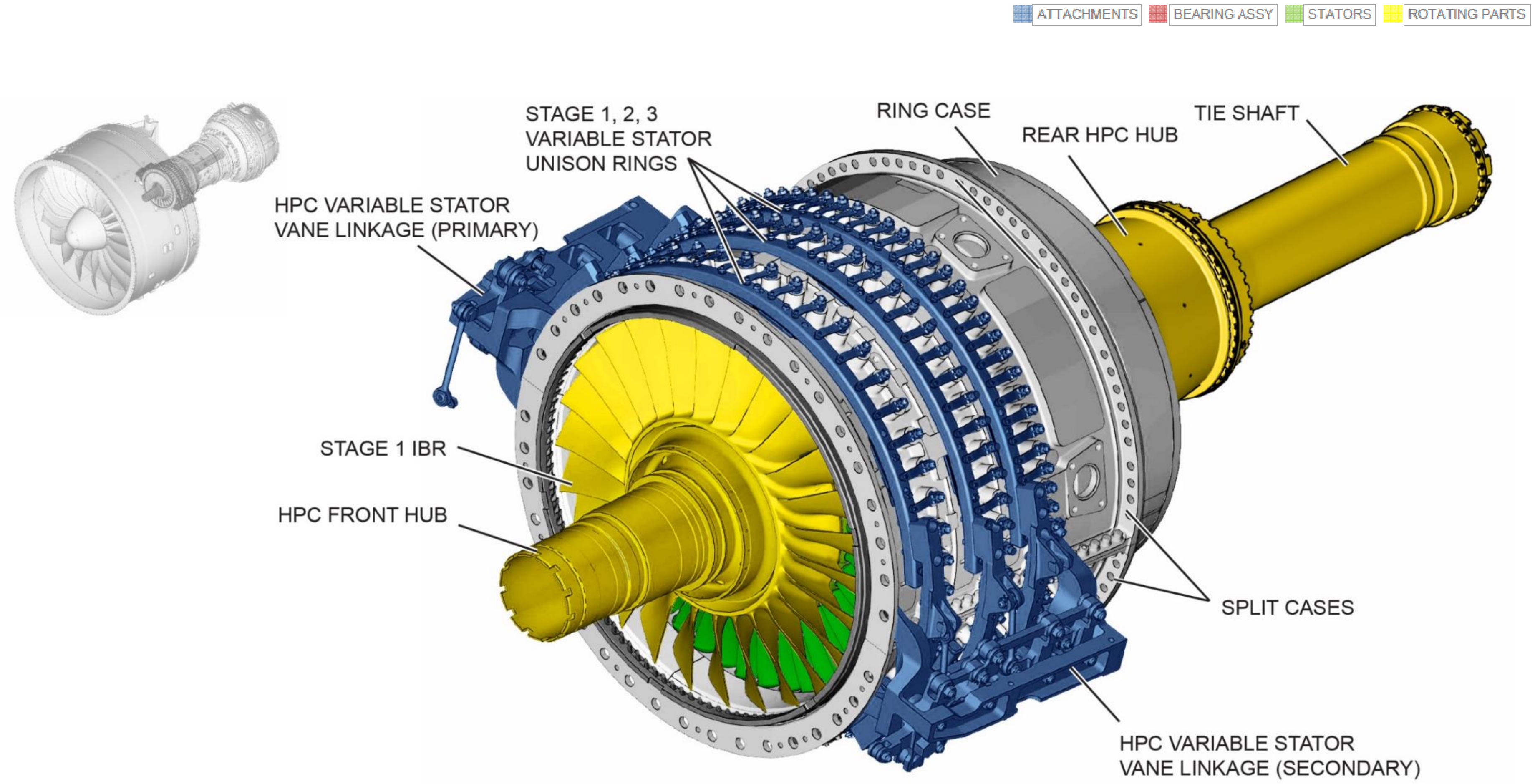
The Variable Inlet Guide Vanes (VIGVs) and the first three stages of the HPC stator vanes are variable for optimal airflow.

The Variable Stator Vanes (VSVs) are connected by a series of unison rings and linkages to primary and secondary actuators.

Remaining stators in stages 4 through 7 are fixed, each vane installed in ring cases that extend inward and seal against a stator rub surface on the adjacent rotor.

The rub surface prevents air from leaking past the end of the vane. The 8th Stage stator (also an Exit Guide Vane) has a cast, one-piece design.

The HPC is powered by the HPT. Engine bleed air from Station 2.5 buffer air and the HPC Stage 7 rotor cools the HPC internally.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
STAGE 1, 2, 3
VARIABLE STATOR
UNISON RINGS
RING CASE
REAR HPC HUB
TIE SHAFT
HPC VARIABLE STATOR
VANE LINKAGE (PRIMARY)
STAGE 1 IBR
HPC FRONT HUB
SPLIT CASES
HPC VARIABLE STATOR
VANE LINKAGE (SECONDARY)

There are eight stages to the HPC, with numbers that start with stage 1.

The first eight rotor stages are of the Integral Blade Rotor (IBR) design, in which the disk and blades are one piece to decrease air leakage.

The eight rotor stages are held together with a tie shaft that connects the HPC front hub and rear hub, and extends rearward to the High-Pressure Turbine (HPT).

The first three stages of the HPC stator vanes are variable-vane design, in which the vane angles are adjusted as necessary for engine operation conditions.

A dual actuator controlled by the Electronic Engine Control (EEC) moves a linkage to turn the vanes of each stage at the same time to the necessary angle.

Knife-edge seals on the 2nd through 4th stage rotors seal against the inner seal lands of the variable stators to control the flow of the air.

The HPC gets its power from the HPT system.

The HPT engages at the front to the HPC rear hub through a curvic coupling and is held together by a retaining nut on the HPC tie shaft at the rear.

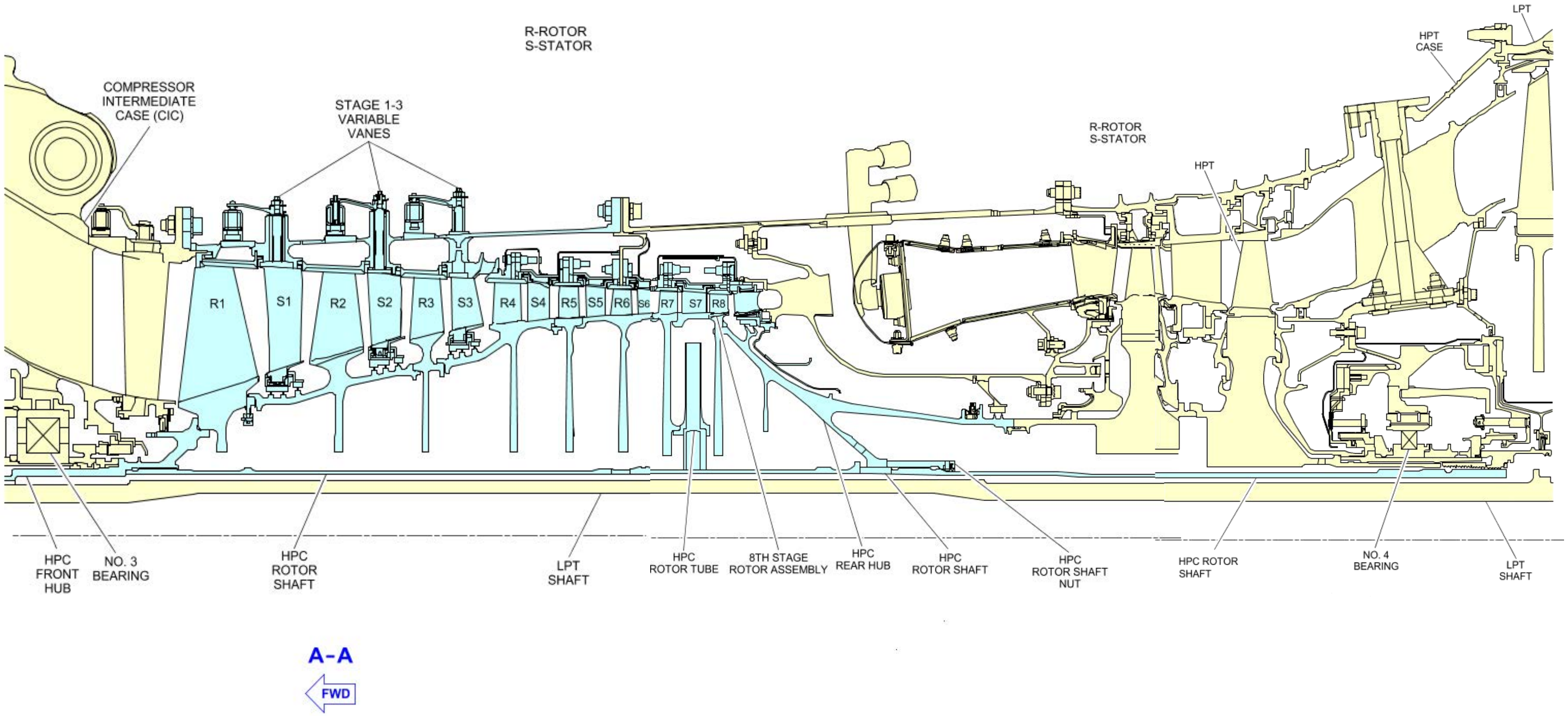
The HPC is held radially and axially at the front by the No. 3 ball bearing in the CIC.

It is held radially at the rear by the No. 4 roller bearing at the end of the HPC rotor shaft.

Between the 7th and 8th stage rotors are eight HPC rotor tubes held in a ring.

These paddles turn with the rotor and push air to the centre of the rotor where this air can flow to where it is necessary for cooling and pressure balance.

These paddles prevent vortices which can cause blockage of necessary internal rotor air movement.


R-ROTOR
S-STATOR
COMPRESSOR INTERMEDIATE CASE (CIC)
STAGE 1-3 VARIABLE VANES
R1
S1
R2
S2
R3
S3
R4
S4
R5
S5
R6
S6
R7
S7
R8
R-ROTOR
S-STATOR
HPT
HPT CASE
LPT
HPC FRONT HUB
NO. 3 BEARING
HPC ROTOR SHAFT
LPT SHAFT
HPC ROTOR TUBE
8TH STAGE ROTOR ASSEMBLY
HPC REAR HUB
HPC ROTOR SHAFT
HPC ROTOR SHAFT NUT
HPC ROTOR SHAFT
NO. 4 BEARING
LPT SHAFT
A-A
FWD

DIFFUSER COMBUSTOR

Purpose:

The diffuser straightens and slows compressed air from the HPC.

It reduces the velocity of the air while increasing its static pressure to permit proper mixing and combustion of the fuel.

The diffuser also offers structural support to the HPC and HPT cases.

The combustor provides a contained space where the fuel and air mix and are ignited and burned to produce energy to turn the turbines.

Location:

The diffuser and combustor are located between the HPC and HPT.

Description:

Within the combustion chamber, fuel nozzles supply metered fuel.

The mix of fuel and air is ignited and burned, causing the air to expand and accelerate rearward.

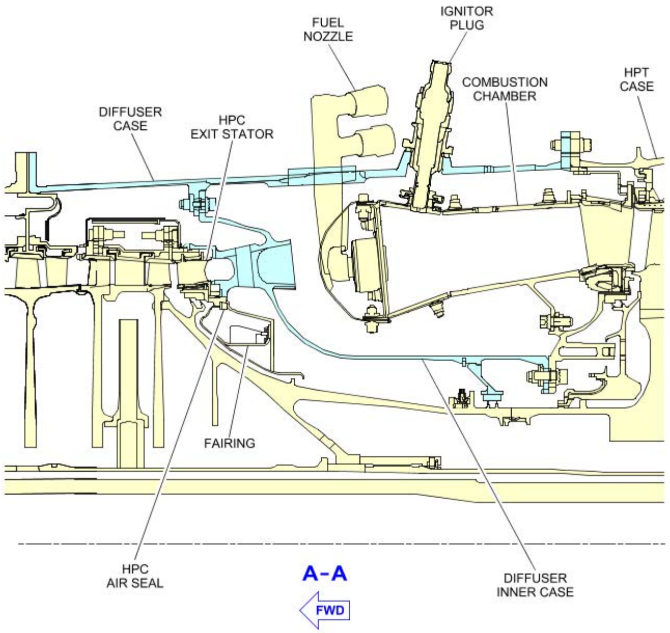
Turbine nozzle guide vanes direct the high-temperature, high velocity gases out of the combustion chamber to drive the turbines.

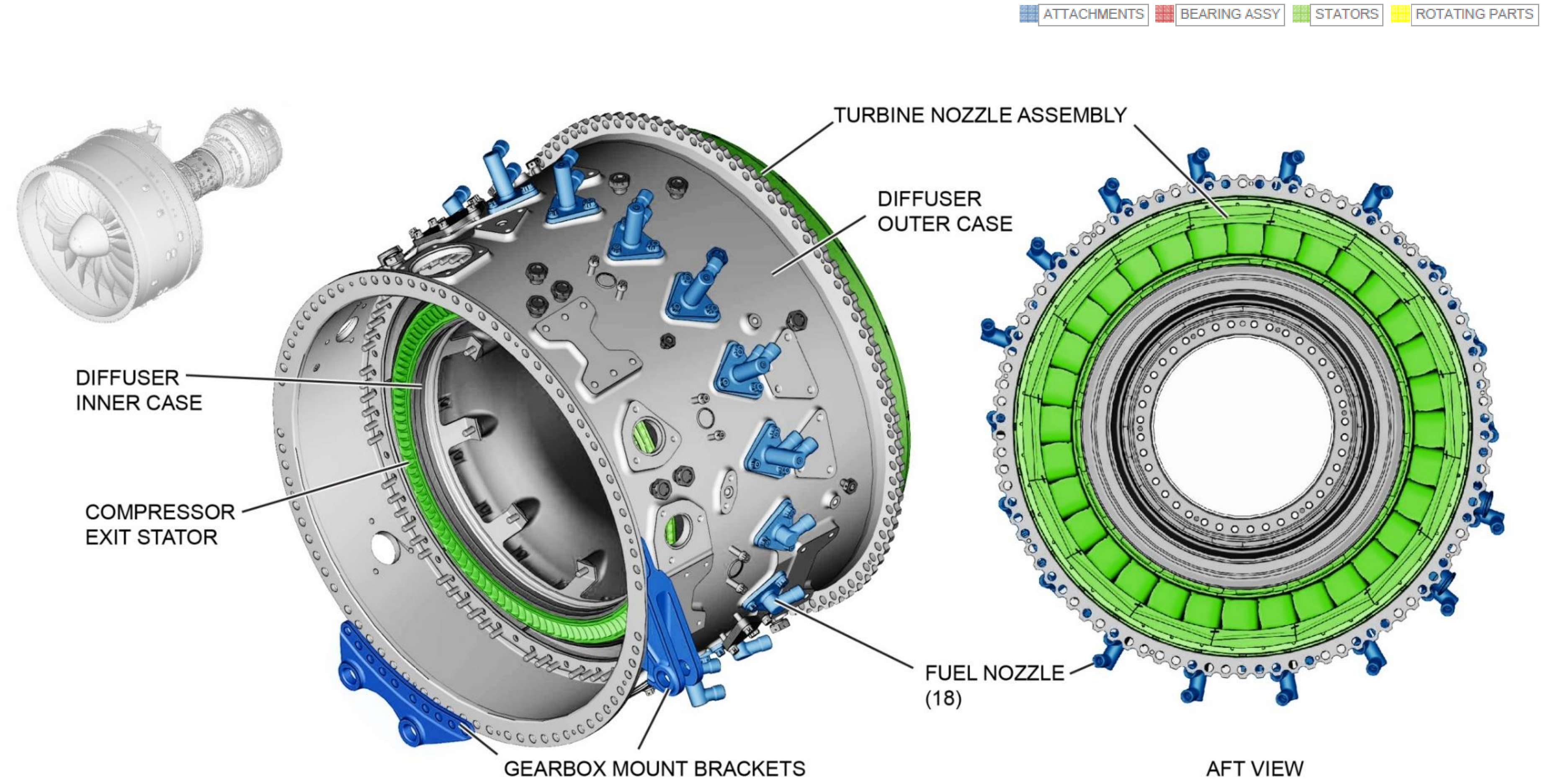
The diffuser/combustor includes the components shown below.

Diffuser case (inner and outer)
Compressor exit stator assembly
Fuel nozzles (18)
Fuel supply manifolds
Igniter plugs (2)
Combustion chamber assembly and turbine nozzle assembly
Main Gearbox mount brackets (2)

The diffuser case assembly houses all the parts of the diffuser, combustion, and turbine nozzle subassemblies.

It also supports the rear of the HPC inner case and provides an outer case for HPC stages 7 and 8




ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
TURBINE NOZZLE ASSEMBLY
DIFFUSER
OUTER CASE
DIFFUSER
INNER CASE
COMPRESSOR
EXIT STATOR
FUEL NOZZLE
(18)
GEARBOX MOUNT BRACKETS
AFT VIEW

TURBINE NOZZLE ASSEMBLY

Purpose:

The Turbine Nozzle Assembly provides the flow path for combustion gases to the 1st Stage turbine blades.

Location:

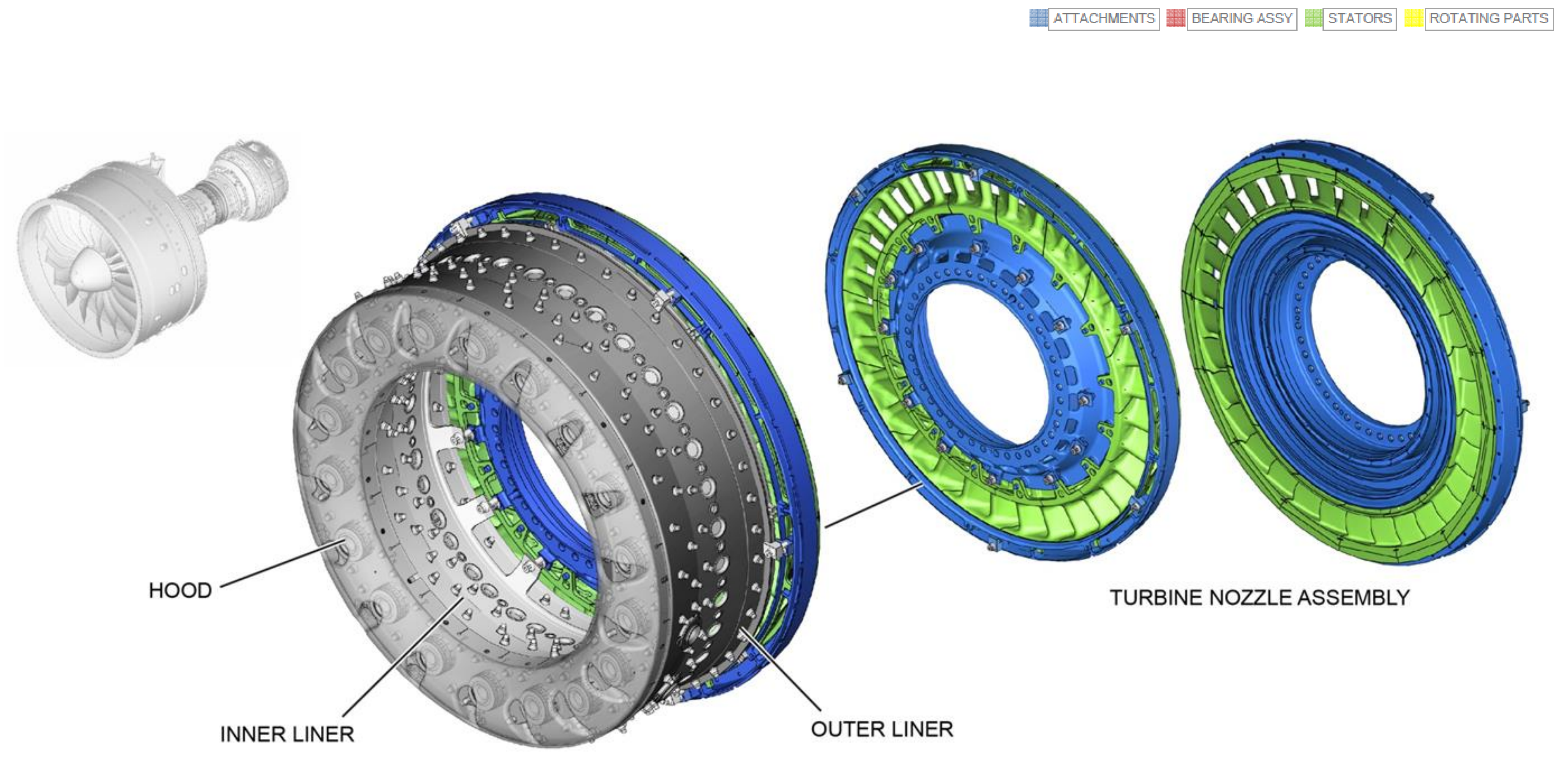
The assembly is located between the combustion chamber and the HPT.

Description:

The assembly incorporates 32 air-cooled guide vanes assembled around the 1st Stage turbine vane (nozzle) support.

Operation:

The ring of vanes changes the direction of the hot gases to provide optimal angle, pressure, and flow to the 1st Stage turbine blades.



COMBUSTION CHAMBER - FRONT VIEW

COMBUSTION CHAMBER

The combustion chamber provides a contained space where the fuel and air mix and are ignited and burned to produce energy.

Location:

The assembly is located within the diffuser case.

Description:

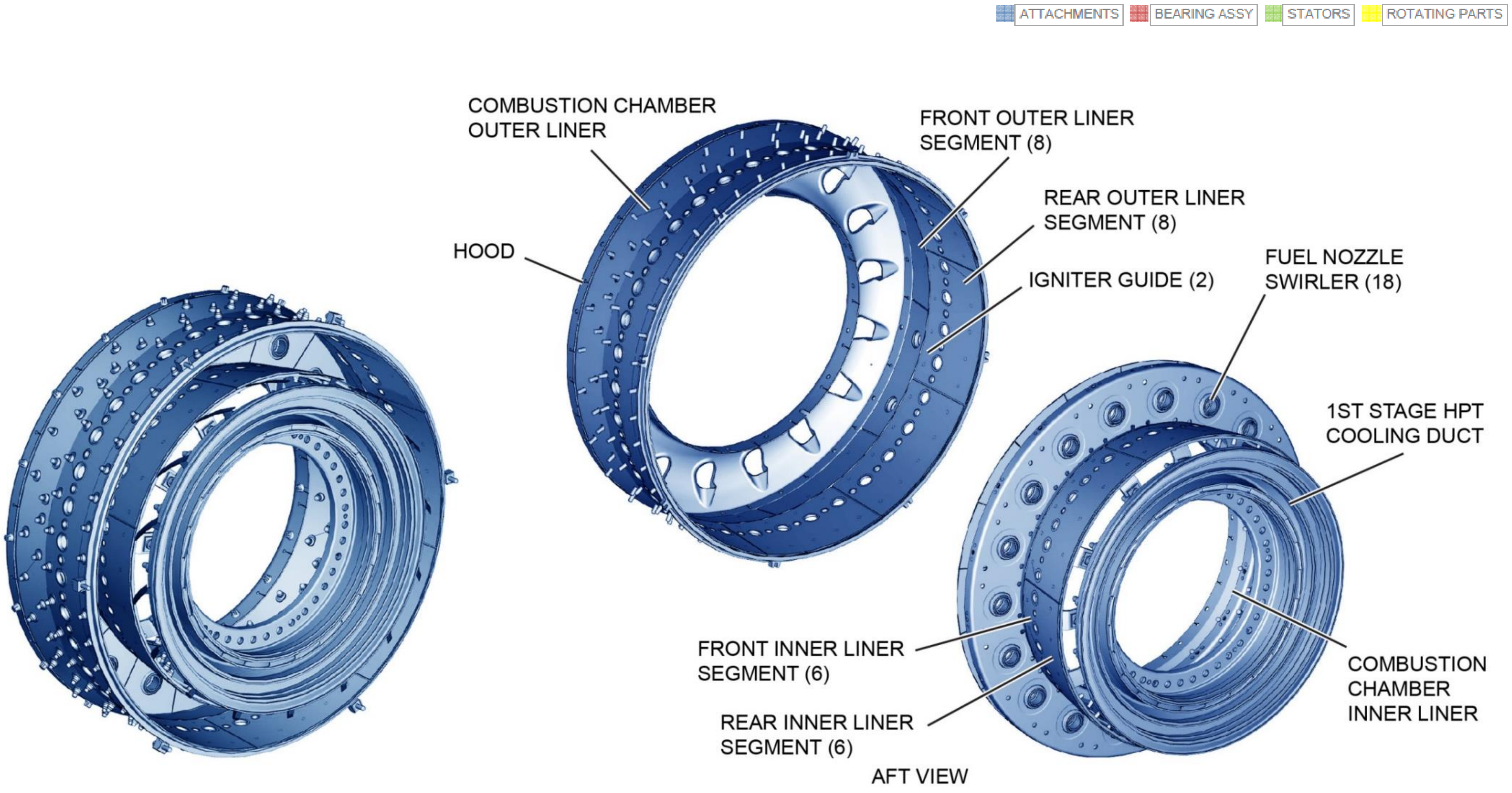
The combustion chamber consists of inner and outer chamber liner assemblies, a bulkhead, and a hood assembly.

The inner and outer liners have replaceable, coated segments that are bolted to a sheet metal liner referred to as a float wall design.

The bulkhead has fuel nozzle guides and swirlers and provides separation of the HPC exit air and combustion gases.

The combustion chamber liner hood distributes the incoming HPC discharge air to both the inner and outer sections of the chamber.

Chamber liners and the hood are bolted to the bulkhead.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
COMBUSTION CHAMBER
OUTER LINER
FRONT OUTER LINER
SEGMENT (8)
REAR OUTER LINER
SEGMENT (8)
HOOD
IGNITER GUIDE (2)
FUEL NOZZLE
SWIRLER (18)
1ST STAGE HPT
COOLING DUCT
FRONT INNER LINER
SEGMENT (6)
REAR INNER LINER
SEGMENT (6)
COMBUSTION
CHAMBER
INNER LINER
AFT VIEW

COMBUSTION CHAMBER AND HIGH-PRESSURE TURBINE (HPT)

Technology for Advanced Low NOx (TALON) combustion chambers are designed for decreased emissions (NOx and smoke).

The combustion chamber is a TALON X trade mark type combustion unit.

The combustion chamber assembly contains an inner and outer liner and a hood and bulkhead at the front.

The bulkhead has ports for the fuel nozzles and openings for HPC air.

The inner and outer liners have combustion holes (which supply combustion air used to burn the fuel) and dilution holes (which mix the air and fuel correctly).

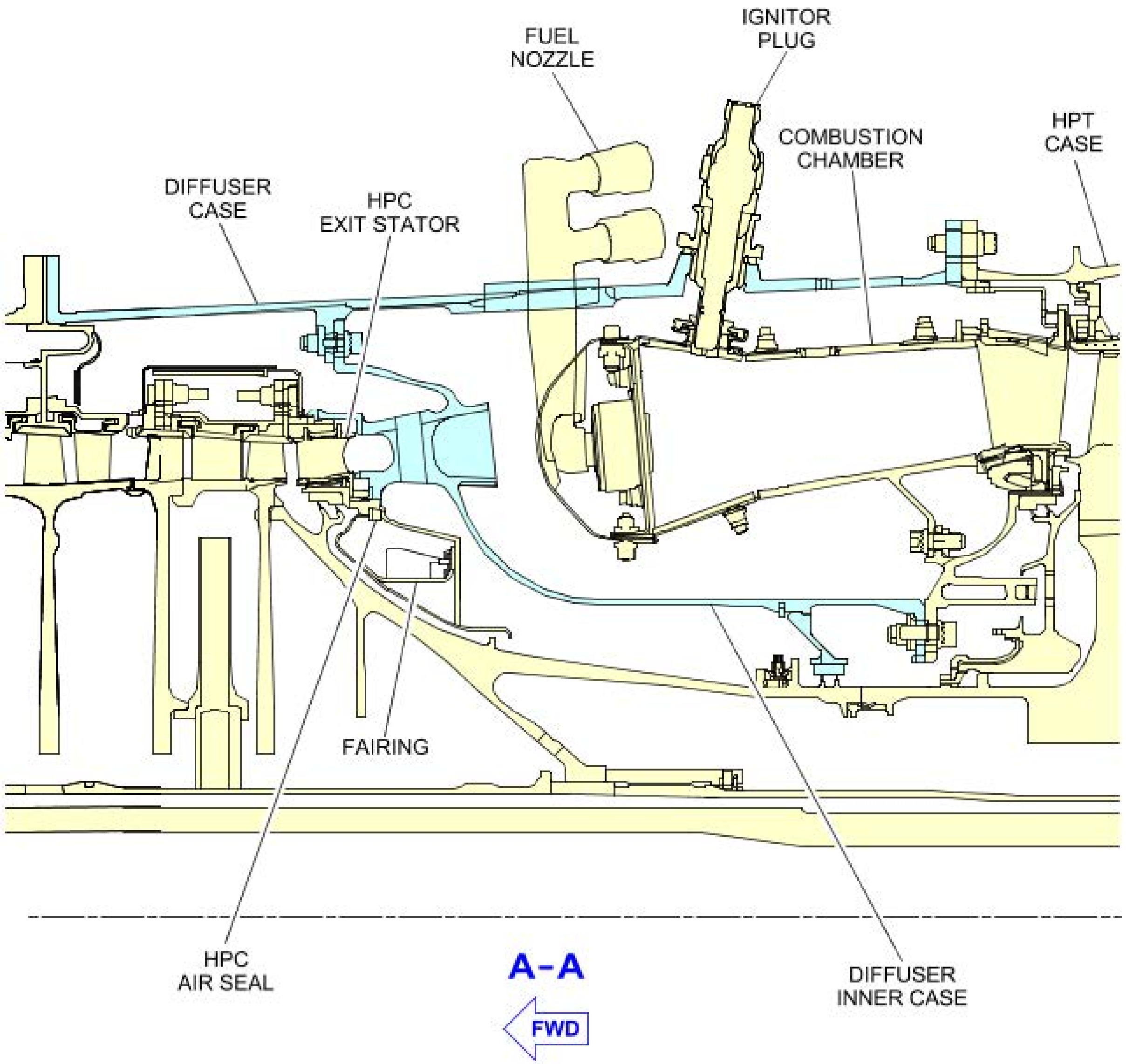
This type of combustion chamber is a float wall design.

The inner and outer liners have cast segments that can be replaced and they have a thermal barrier layer.

There are ports in the sides of the outer liner for igniter plugs which are used to start and continue fuel combustion.

The combustion chamber mixes air and fuel and burns this mixture to expand the volume of gas.

The gas then moves to the HPT 32 vane 1st stage nozzle, which turns the gases through vanes at the correct angle to go into the HPT.


FUEL
NOZZLE
IGNITOR
PLUG
COMBUSTION
CHAMBER
HPT
CASE
DIFFUSER
CASE
HPC
EXIT STATOR
FAIRING
HPC
AIR SEAL
A-A
FWD
DIFFUSER
INNER CASE

HIGH PRESSURE TURBINE (HPT)

Purpose:

The High-Pressure Turbine provides the rotational force to drive the High-Pressure Compressor (HPC) by extracting energy from the hot combustion gases.

Location:

The HPT is located between the combustor and the Turbine Intermediate Case.

Description:

The HPT is made up of two assemblies: a two-stage rotor, and a turbine case and vanes.

Rotor Assembly

Each stage of the two-stage rotor assembly has 44 blades installed to firtree slots in the rotor disk. A rotating knife-edge seal is located at the front and rear of the rotor to control air leakage.

The HPT blades have a thermal barrier coating and are internally cooled to enhance ability to withstand high temperatures.

At the front hub of the 1st Stage turbine rotor is a coupling that meshes with the HPC rear hub, allowing the HPT to drive the HPC rotor assembly.

A bore is machined in the aft of the inner diameter of the 2nd Stage hub, providing a tight fit with the tie-shaft to help support the HPT rotor assembly.

The two hubs are connected by intermeshing castellation’s.

An HPT retaining nut installed at the aft end of the tie-shaft provides axial retention of the HPT rotor assembly. The HPT rotor is supported radially by the No. 4 Bearing.

Turbine Case and Vane

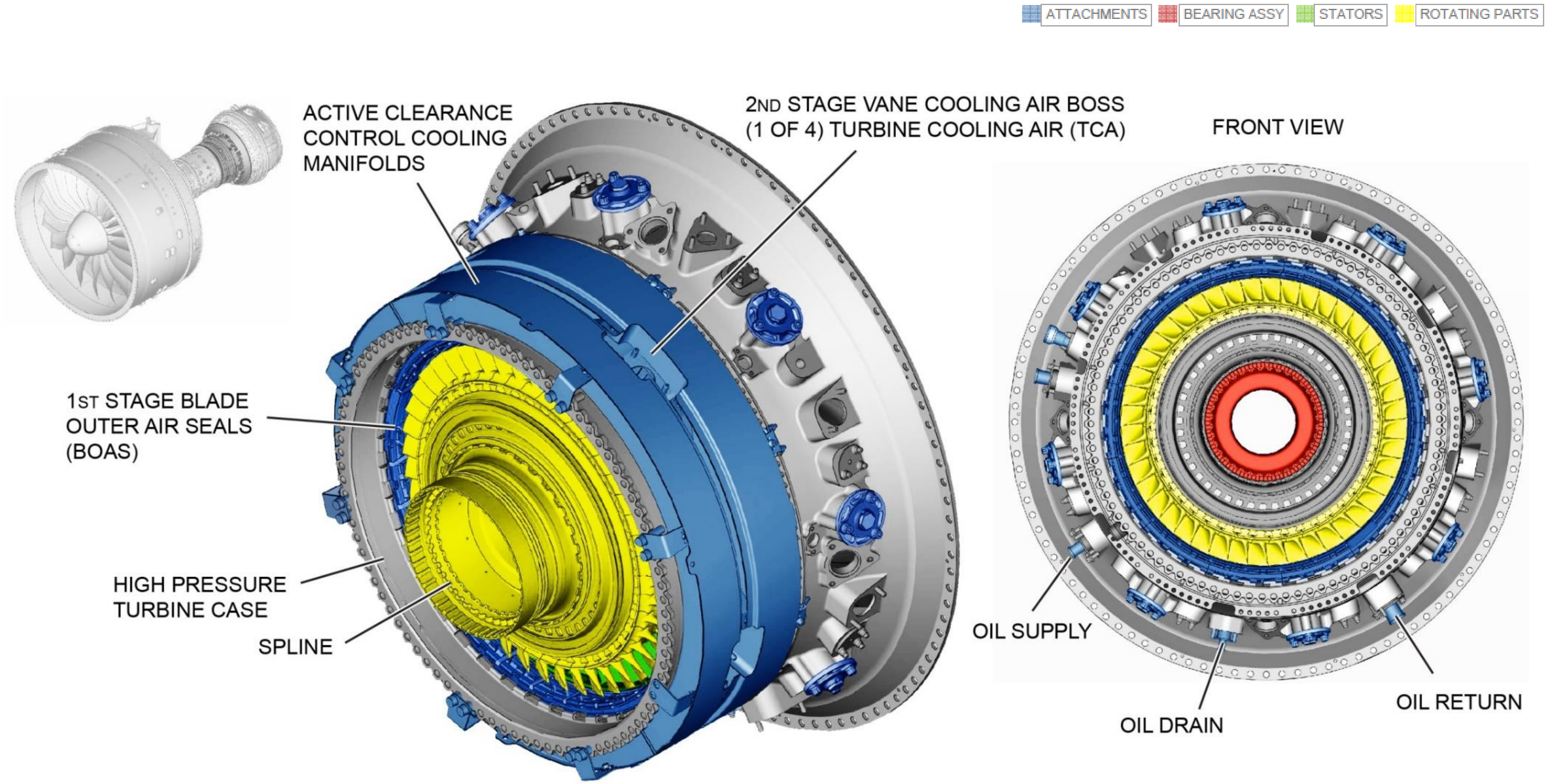
The HPT case supports the 2nd Stage vanes positioned between the turbine rotors. The vanes direct air from the 1st Stage to the 2nd Stage at the optimum angle and pressure.

The 2nd Stage vanes are hollow to allow internal cooling of the vanes.

Temperatures are kept as low as possible by the Turbine Cooling Air (TCA) system that supplies cooling air through the cooling air bosses in the HPT case.

Blade Outer Air Seals (BOAS) are installed to the HPT case for both 1st and 2nd stage blades. BOAS provide a sealing surface for the blade tips that reduces air leakage and improves performance.

The HPT case features Active Clearance Control cooling manifolds around the outside to control blade tip clearance.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
ACTIVE CLEARANCE CONTROL COOLING MANIFOLDS
2ND STAGE VANE COOLING AIR BOSS (1 OF 4) TURBINE COOLING AIR (TCA)
FRONT VIEW
1ST STAGE BLADE OUTER AIR SEALS (BOAS)
HIGH PRESSURE TURBINE CASE
SPLINE
OIL SUPPLY
OIL DRAIN
OIL RETURN

HPT OPERATION

The HPT uses the gas pressure from the High-Pressure Compressor (HPC) with the increased fuel energy from the combustion chamber to turn a two-stage turbine.

The torque of this turbine turns the HPC through the HPC shaft.

The HPT and HPC turn clockwise while the Low-Pressure Compressor (LPC) and Low-Pressure Turbine (LPT) turn counter clockwise for increased efficiency.

A 1st stage seal at the front of the HPT assembly and a 2nd stage seal at the rear of the assembly have knife-edge seals which turn against sealing rings to control air leakage.

These 1st and 2nd stage seals have counterweight flanges to make it possible to correct the unbalance of the HPT assembly.

There are 44 blades in each of the HPT 1st and 2nd stage hubs, which have a controlled clearance with HPT case seals at their tips.

The seals are in segments that let them move as a result of temperature changes.

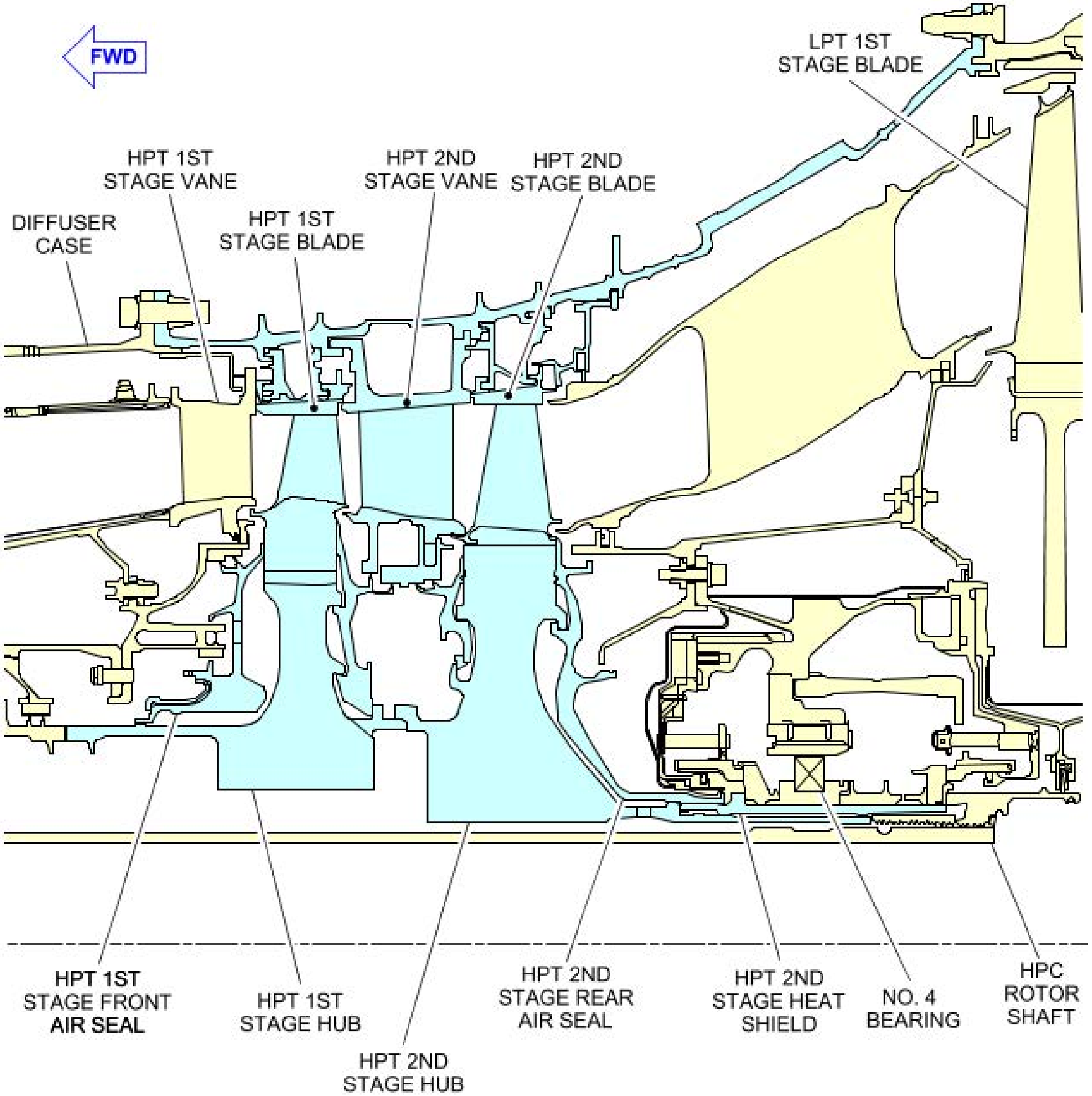
An Active Clearance Control (ACC) system uses fan air manifolds around the outer HPT case to change blade tip clearances.

When necessary (for example during climb or cruise operation), fan discharge air in the manifold applied against the HPT case outer rails makes the case cooler and decreases the inner diameter of the 1st and 2nd stage seal segments.

This decreases the 1st and 2nd stage blade tip clearances and increases the efficiency of the turbine.

The HPT 1st stage blades are kept at the lowest temperature possible with diffuser area air from around the combustion chamber.

This air flows through the cooling air duct and into the openings in the hub and blade roots and from there into the blade aerofoils.


FWD
LPT 1ST STAGE BLADE
HPT 1ST STAGE VANE
HPT 2ND STAGE VANE
HPT 2ND STAGE BLADE
DIFFUSER CASE
HPT 1ST STAGE BLADE
HPT 1ST STAGE FRONT AIR SEAL
HPT 1ST STAGE HUB
HPT 2ND STAGE HUB
HPT 2ND STAGE REAR AIR SEAL
HPT 2ND STAGE HEAT SHIELD
NO. 4 BEARING
HPC ROTOR SHAFT

TURBINE INTERMEDIATE CASE (TIC)

Purpose:

The Turbine Intermediate Case directs the HPT gas path airflow to align with the counter-rotating LPT, and supports the No. 4 Bearing.

Location:

The TIC is integrated within the HPT Assembly.

Description:

The module houses the turbine stator assembly and the No. 4 roller bearing assembly.

Turbine Stator Assembly

A turbine stator assembly between the inner and outer cases has 16 stator vanes. Vanes have an aerofoil contour that turns the HPT gas path airflow to align with the LPT.

The Turbine Intermediate Case uses eight support rods to connect the inner and outer cases through bosses in the stator vanes.

Pressure, scavenge and drain oil tubes from the No. 4 Bearing compartment go through three of the remaining vane bosses. Stator vanes protect the support rods and tubes from high gas path temperatures.

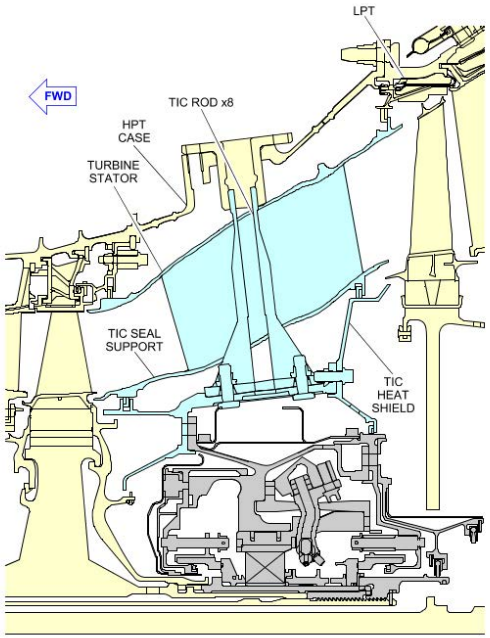
No. 4 Roller Bearing Assembly

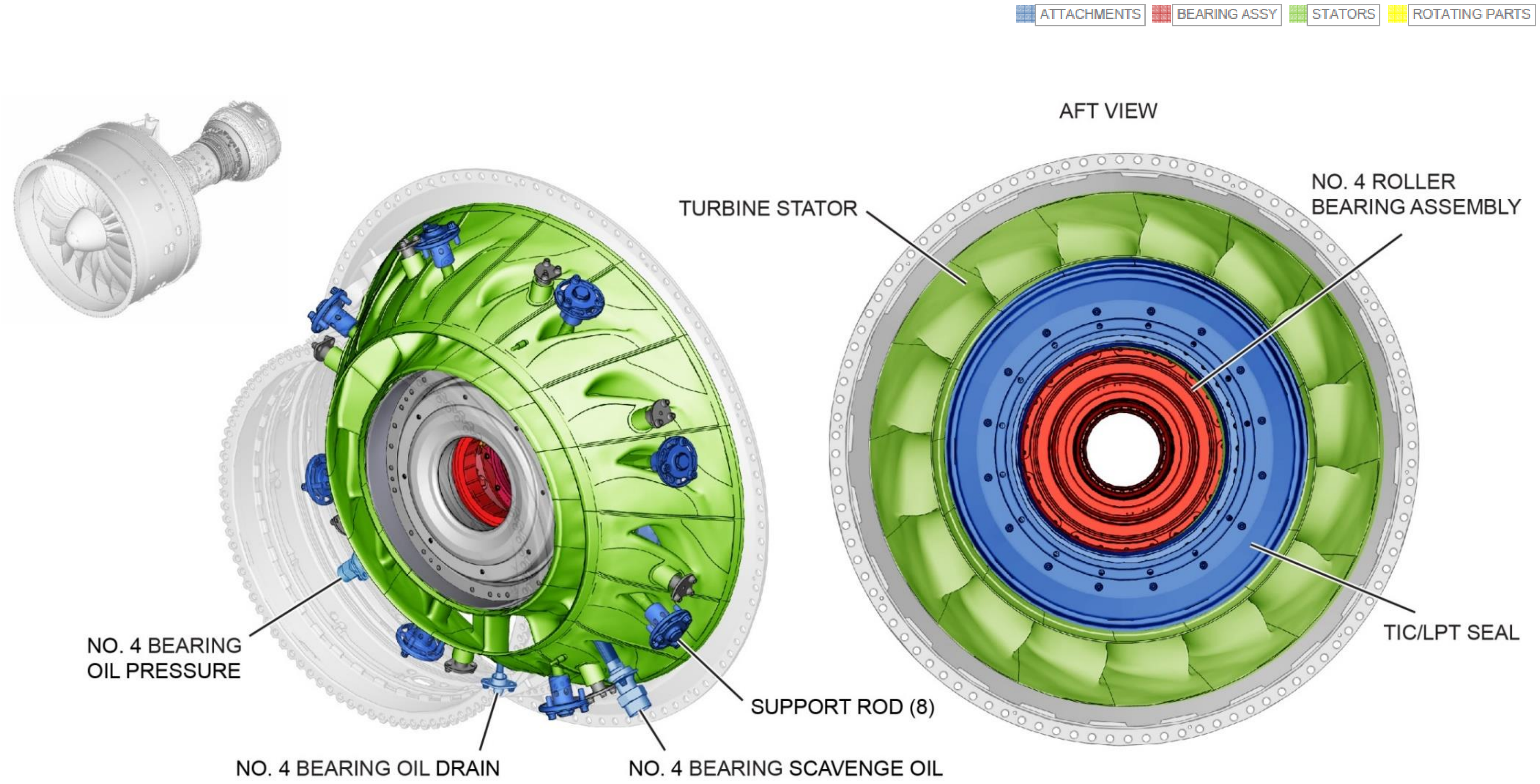
The No. 4 roller bearing assembly supports the rear of the HPT rotor and contains the No. 4 Bearing support, attached to the inner case.

The oil damped assembly maintains a pressurized oil film around the bearing outer race to absorb rotor vibration.

No. 4 Bearing compartment oil leakage is controlled by carbon seals at the front and rear of the compartment, and by buffer sealing air supplied by a buffer air tube.

Buffer air cools the compartment and prevents oil from *coking*, or heating to the point of solidifying.




ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
AFT VIEW
TURBINE STATOR
NO. 4 ROLLER
BEARING ASSEMBLY
TIC/LPT SEAL
NO. 4 BEARING
OIL PRESSURE
SUPPORT ROD (8)
NO. 4 BEARING OIL DRAIN
NO. 4 BEARING SCAVENGE OIL

LOW PRESSURE TURBINE (LPT)

Purpose:

The Low-Pressure Turbine provides rotational driving force for the Low-Pressure Compressor and Fan Drive Gear System by extracting energy from the hot combustion gases.

Location:

The LPT is located between the TIC and the Turbine Exhaust Case.

Description:

The LPT consists of these components:

three-stage rotor assembly
LPT shaft
second and third stage turbine vanes
turbine case assembly.

The LPT drives the LPC and FDGS by extracting energy from the hot combustion gases, using the turbine blade and rotor assemblies.

The spinning rotors are connected to the LPC by a turbine shaft that runs through the centre of the engine.

Viewed from the rear, the LPT rotates in a counter clockwise direction, the opposite of the HPT.

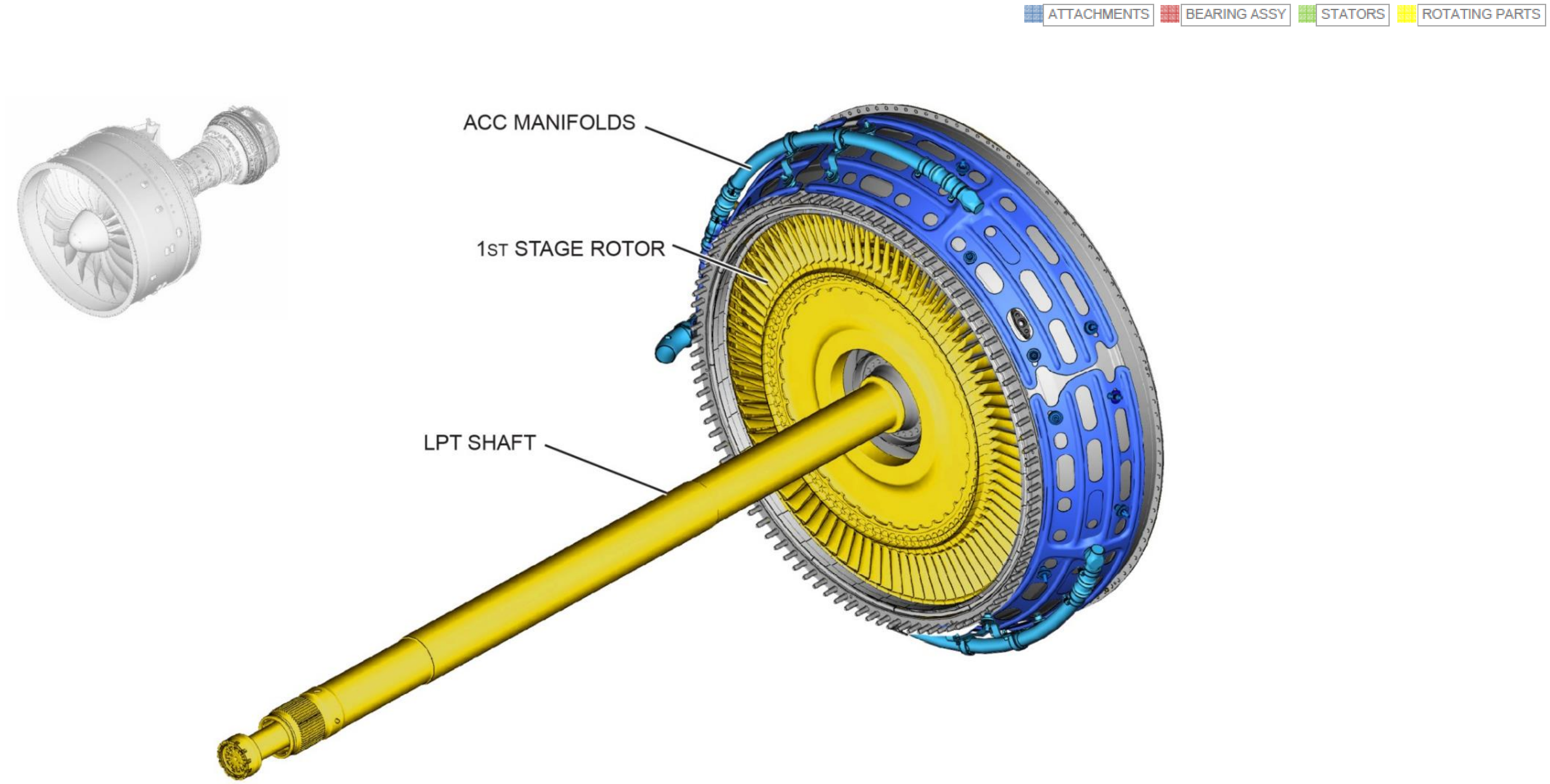
The 2nd Stage hub provides a splined attachment for the LPT shaft.

The 1st and 3rd stage disks are bolted to the 2nd Stage hub and are cantilevered forward and aft.

Disks feature integral rotating knife-edge air seals to limit gas path leakage around the inner diameter of the stator vanes.

All three turbine blade stages and second stage vanes are coated to protect against oxidation and sulfidation.

The LPT case is cooled by the Active Clearance Control (ACC) manifolds.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
ACC MANIFOLDS
1ST STAGE ROTOR
LPT SHAFT

LPT Operation

Gas flow from the HPT is turned by the Turbine Intermediate Case (TIC) vanes and is changed to torque by the LPT.

1. The LPT is connected to the Low-Pressure Compressor (LPC) through the LPT shaft and uses this torque to turn the LPC.

2. The LPT and LPC turn counter clockwise as seen from the rear.

3. The HPT and High-Pressure Compressor (HPC) turn clockwise.

The LPT has three stages, an LPT 1st and 3rd stage attached to an LPT 2nd stage hub with a single circle of tie bolts.

NOTE: Each compressor and turbine rotor has stages whose number starts at one. For the LPT, the stages are the 1st thru 3rd.

Gas leakage at the LPT blade tips is controlled by outer-air seal segments.

These segments keep a controlled clearance with the adjacent blade tip knife-edges.

The LPT has an Active Clearance Control (ACC) system.

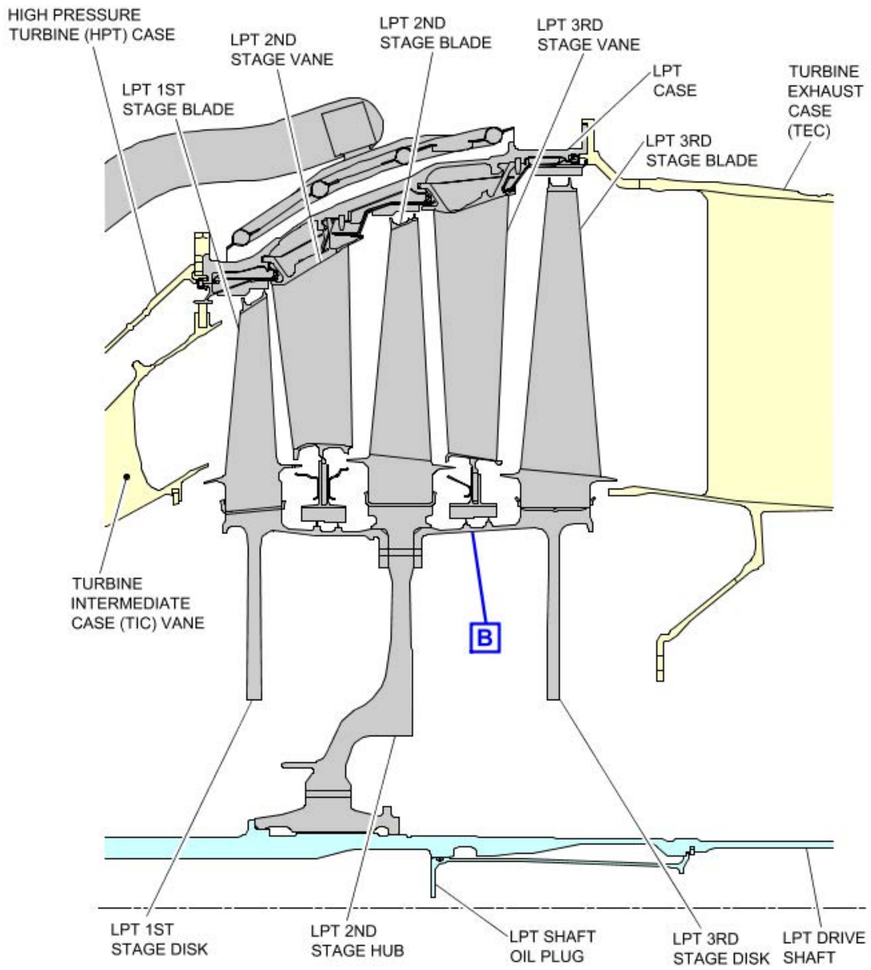
With this system, a Turbine Cooling Air (TCA) valve (energized by the Electronic Engine Control (EEC)) controls Fan Air and sends it to a panel assembly around the LPT case.

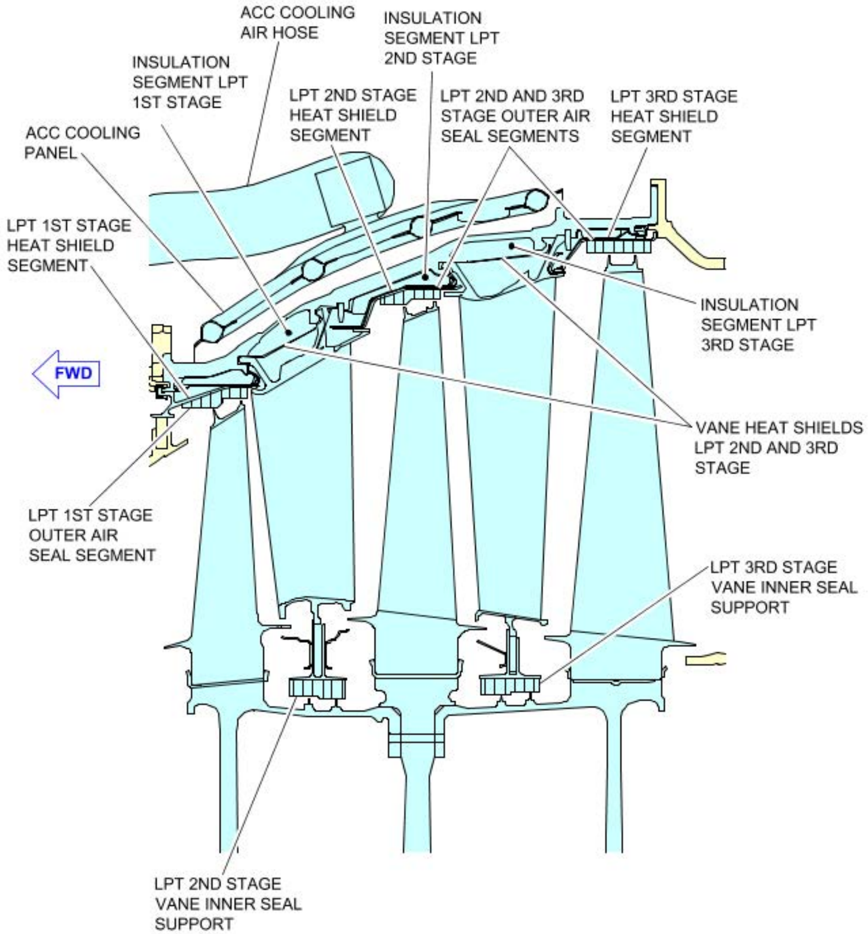
This Fan Air from the ACC cooling panels makes the LPT case cooler and decreases its diameter.

This decreases the diameter of the outer air seal segments which causes tighter clearances at the 1st thru 3rd stage blade tips and increased engine efficiency.

Gas leakage between the rotor stages is controlled by fin-type inner air seal segments attached to inner seal supports at the LPT 2nd and 3rd stage vane inner feet.

These segments keep a controlled clearance with knife edges on the 1st and 3rd stage turbine rotor flanges.


HIGH PRESSURE TURBINE (HPT) CASE
LPT 2ND STAGE VANE
LPT 2ND STAGE BLADE
LPT 3RD STAGE VANE
LPT 1ST STAGE BLADE
LPT CASE
TURBINE EXHAUST CASE (TEC)
LPT 3RD STAGE BLADE
B
TURBINE INTERMEDIATE CASE (TIC) VANE
LPT 1ST STAGE DISK
LPT 2ND STAGE HUB
LPT SHAFT OIL PLUG
LPT 3RD STAGE DISK
LPT DRIVE SHAFT


ACC COOLING AIR HOSE
INSULATION SEGMENT LPT 2ND STAGE
INSULATION SEGMENT LPT 1ST STAGE
LPT 2ND STAGE HEAT SHIELD SEGMENT
LPT 2ND AND 3RD STAGE OUTER AIR SEAL SEGMENTS
LPT 3RD STAGE HEAT SHIELD SEGMENT
ACC COOLING PANEL
LPT 1ST STAGE HEAT SHIELD SEGMENT
FWD
INSULATION SEGMENT LPT 3RD STAGE
VANE HEAT SHIELDS LPT 2ND AND 3RD STAGE
LPT 1ST STAGE OUTER AIR SEAL SEGMENT
LPT 3RD STAGE VANE INNER SEAL SUPPORT
LPT 2ND STAGE VANE INNER SEAL SUPPORT

TURBINE EXHAUST CASE (TEC)

Purpose:

The Turbine Exhaust Case is a main structural case that supports two main bearings and the rear engine mount, forming a transitional duct that collects and straightens exhaust gases.

Location:

The TEC attaches to the rear of the Low-Pressure Turbine.

Description:

The TEC is a one-piece case assembly that supports roller bearing nos. 5 and 6. It has attachment points for the rear engine mount and the exhaust nozzle and centre body.

Ten hollow struts provide radial support between the inner and outer cases.

The bearings provide radial support for the LPT.

The No. 6 Bearing is oil-damped. Oil leakage is controlled by a face-type carbon seal at the forward side of the No. 5 Bearing, and by an oil plug at the rear of the LPT shaft.

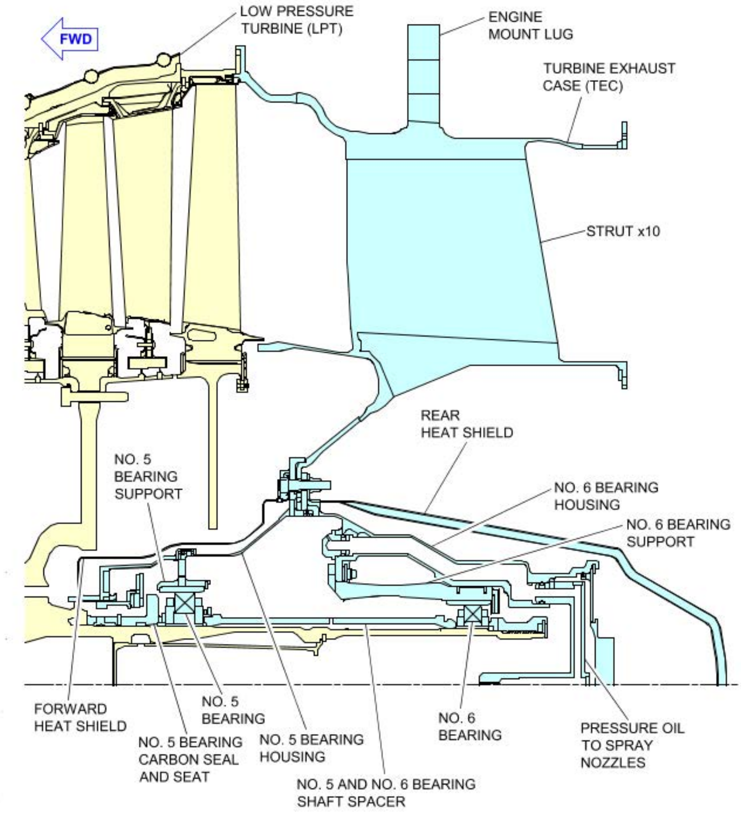
A heat shield reduces the high temperatures that can cause coking in the bearing compartment.

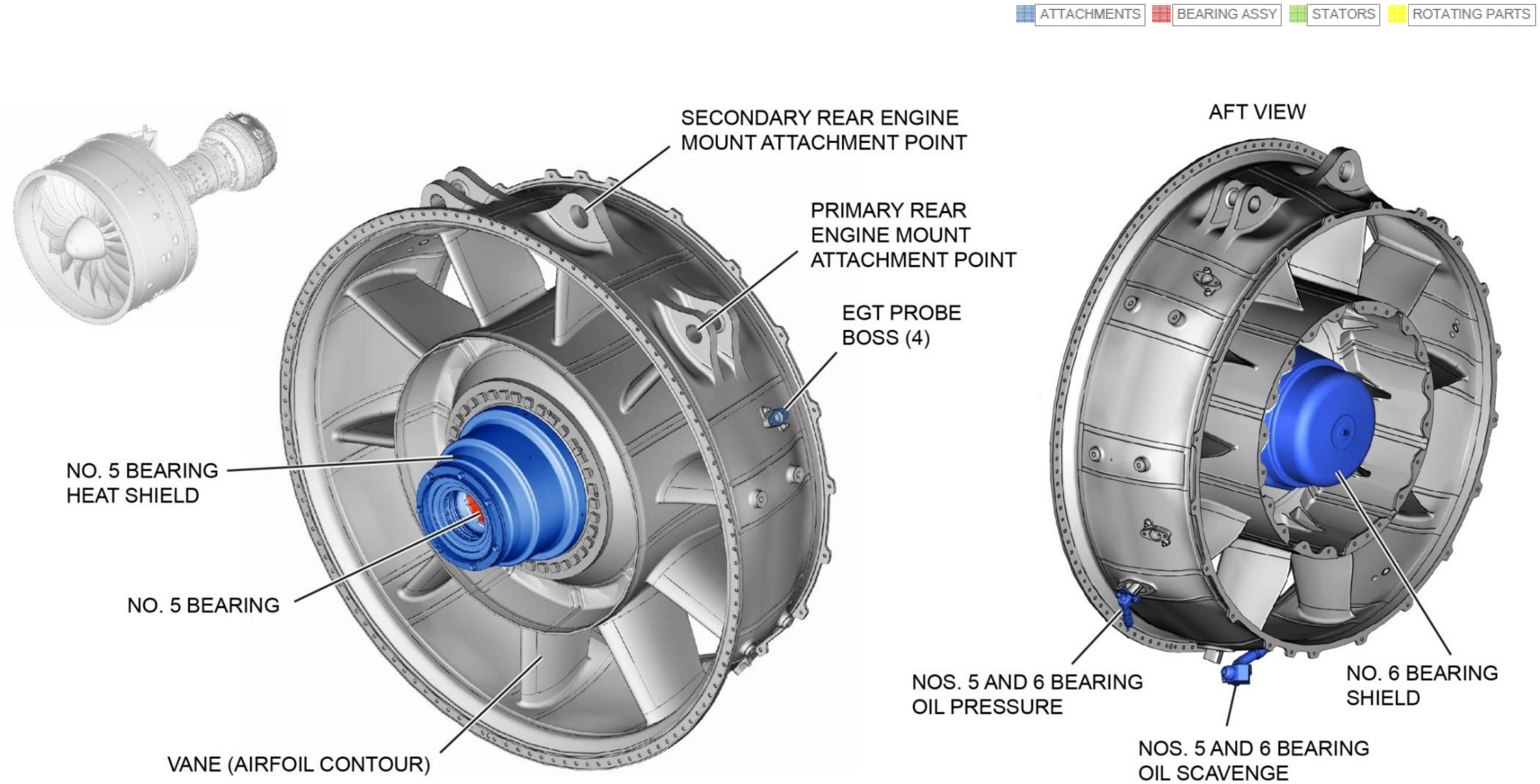
Oil and scavenge tubes for the bearings go through the bottom struts of the TEC.

Four exhaust gas temperature probes are mounted to bosses on the TEC outer case.

The TEC also has mount points for Ground Support Equipment (GSE).

Integral to the outer case of the TEC are two primary and one secondary rear mount attachment points for the engine mount links that transmit the engine thrust loads to the airframe.




ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
SECONDARY REAR ENGINE MOUNT ATTACHMENT POINT
PRIMARY REAR ENGINE MOUNT ATTACHMENT POINT
EGT PROBE BOSS (4)
NO. 5 BEARING HEAT SHIELD
NO. 5 BEARING
VANE (AIRFOIL CONTOUR)
AFT VIEW
NOS. 5 AND 6 BEARING OIL PRESSURE
NO. 6 BEARING SHIELD
NOS. 5 AND 6 BEARING OIL SCAVENGE

MAIN GEARBOX (MGB)

Purpose:

The Main Gearbox extracts mechanical power from the engine to drive system accessories that are mounted to pads on its forward and aft sides.

Location:

The MGB is mounted to brackets at 4:00 and 9:00 on the diffuser case.

Description:

The Main Gearbox is a cast aluminium housing that contains gear sets and shafts to transmit mechanical power. Power from the MGB drives components in four system types: electrical, fuel, oil, and hydraulic.

The Main Gearbox Assembly is attached to the engine core at five locations using a series of brackets and links.

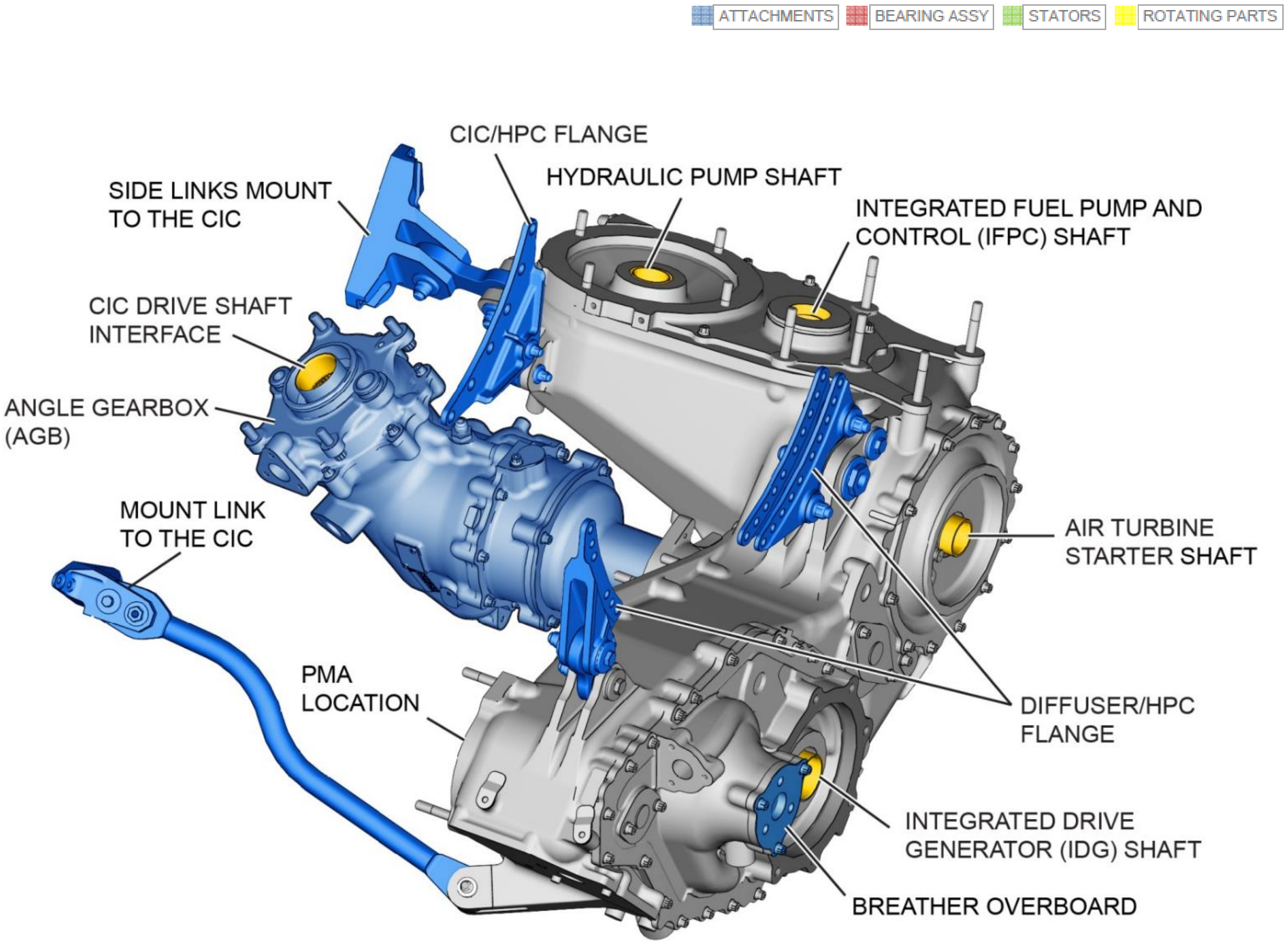
The mounting bracket configuration is designed to ensure that failure of the mounting hardware is improbable.

The configuration protects the links and mounting brackets from damage if the Main Gearbox should experience high loads due to a fan blade fracture.

Internal casting passages called *coring* supply oil to bearings and components. Carbon seals prevent oil leakage through the MGB front and rear walls.

A de-oiler at the left rear of the MGB (aft looking forward) removes oil vapor from internal breather air before the air is released from the engine.

A crank pad is located at the right rear of the MGB housing to turn the HPC/HPT rotors when necessary for inspection.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
CIC/HPC FLANGE
HYDRAULIC PUMP SHAFT
SIDE LINKS MOUNT TO THE CIC
INTEGRATED FUEL PUMP AND CONTROL (IFPC) SHAFT
CIC DRIVE SHAFT INTERFACE
ANGLE GEARBOX (AGB)
MOUNT LINK TO THE CIC
AIR TURBINE STARTER SHAFT
PMA LOCATION
DIFFUSER/HPC FLANGE
INTEGRATED DRIVE GENERATOR (IDG) SHAFT
BREATHER OVERBOARD

MAIN GEARBOX (MGB)

Description (Cont.)

Components shown in the table are mounted to the Main Gearbox.

Operation:

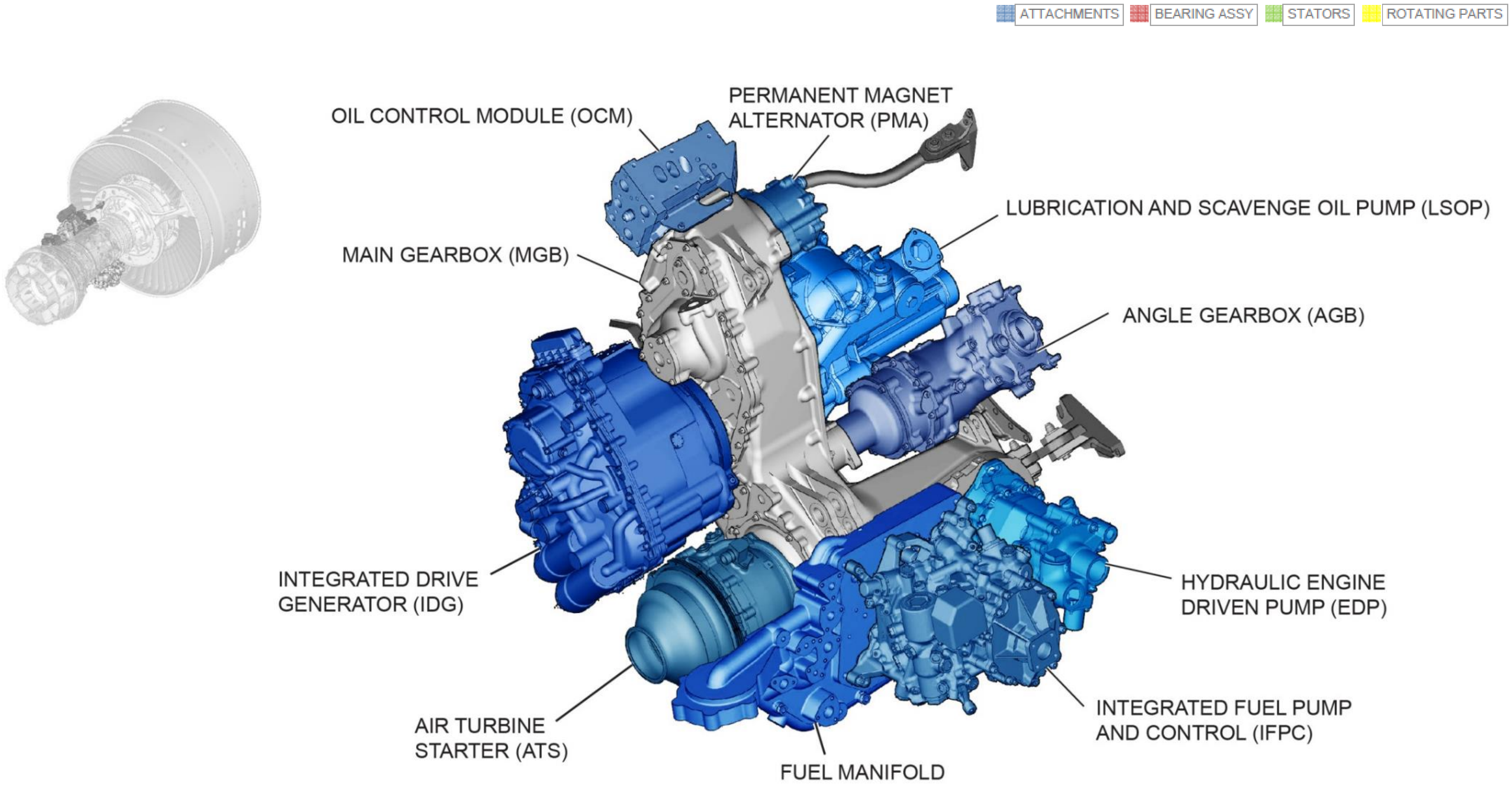
1. A gearbox drive shaft in the Compressor Intermediate Case (CIC) engages the No. 3 Bearing bevel gear on the front of the HPC shaft.

2. The HPC/HPT rotational energy is transferred to the CIC tower shaft to the Angle Gearbox.

3. Torque coming through the Angle Gearbox is supplied to the MGB through the MGB lay shaft.

The MGB uses this power to drive components for a variety of systems.

<table>
<tr><th>Component</th><th>System Type</th><th>Location</th></tr>
<tr><td>Integrated Fuel Pump and Control</td><td rowspan="2">Fuel</td><td rowspan="3">Right Side</td></tr>
<tr><td>Fuel Manifold</td></tr>
<tr><td>Hydraulic Engine Driven Pump</td><td>Hydraulic</td></tr>
<tr><td>Oil Control Module</td><td rowspan="2">Oil</td><td>Left Side</td></tr>
<tr><td>Lubrication and Scavenge Oil Pump</td><td rowspan="2">Front</td></tr>
<tr><td>Permanent Magnet Alternator</td><td>Electrical</td></tr>
<tr><td>Air Turbine Starter</td><td>Air</td><td rowspan="2">Rear</td></tr>
<tr><td>Integrated Drive Generator</td><td>Electrical</td></tr>
</table>


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
OIL CONTROL MODULE (OCM)
PERMANENT MAGNET ALTERNATOR (PMA)
LUBRICATION AND SCAVENGE OIL PUMP (LSOP)
MAIN GEARBOX (MGB)
ANGLE GEARBOX (AGB)
INTEGRATED DRIVE GENERATOR (IDG)
HYDRAULIC ENGINE DRIVEN PUMP (EDP)
AIR TURBINE STARTER (ATS)
INTEGRATED FUEL PUMP AND CONTROL (IFPC)
FUEL MANIFOLD

ANGLE GEARBOX (AGB)

Purpose:

The Angle Gearbox extracts power from the HPC and provides it to the MGB through a series of gear shafts.

Location:

The AGB is located at 6:00 on the engine core, between the Compressor Intermediate Case and the Main Gearbox Assembly.

Description:

The AGB Assembly contains the Angle Gearbox housing, gear shafts, lay shaft and lay shaft covers.

The AGB acts as a connection between the HPC and the MGB.

The MGB drive shaft passes through a front and rear cover.

The AGB housing supports ball and roller bearings that hold the gear shafts in position.

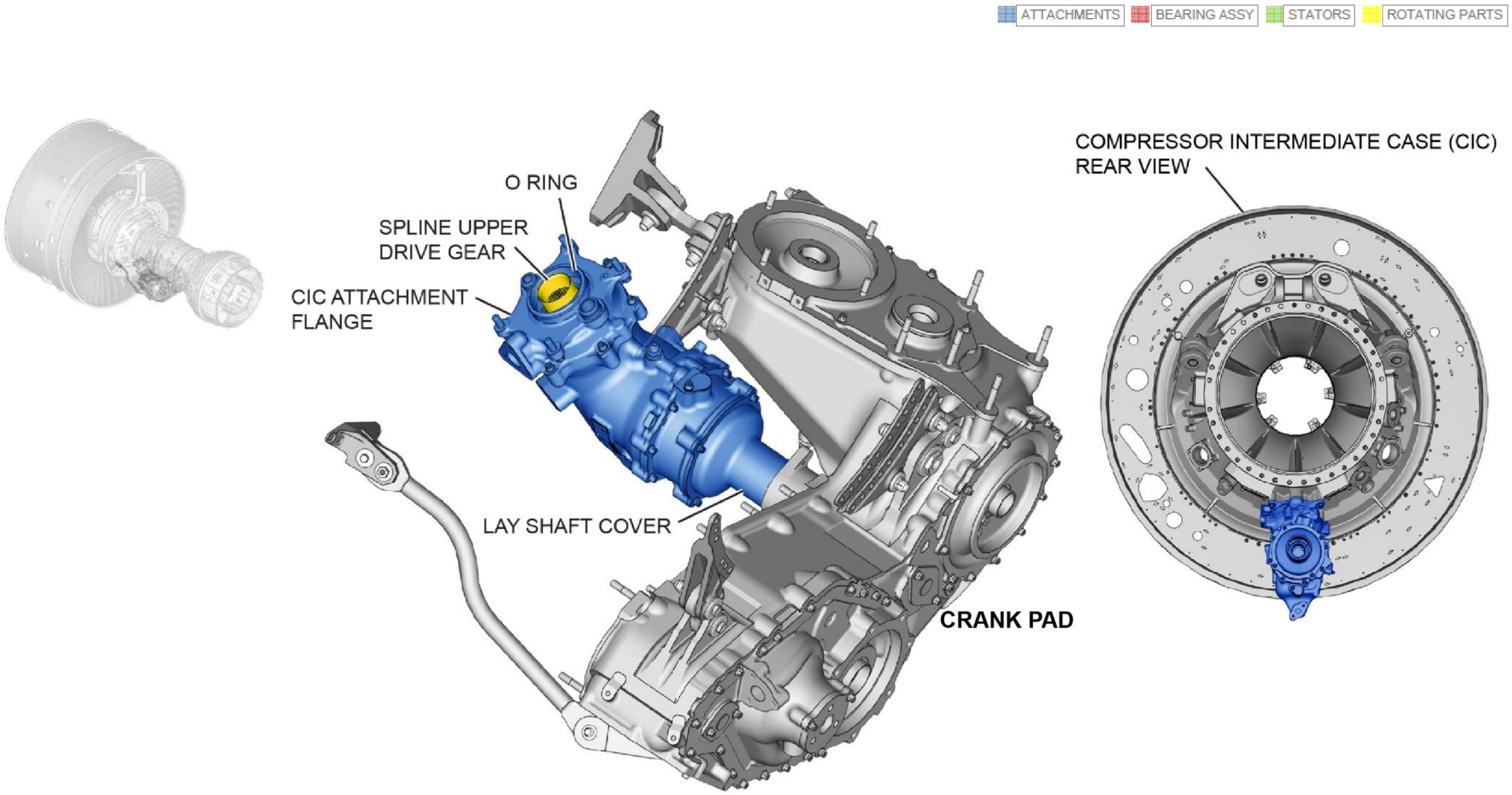
The CIC attachment flange and O rings are part of the housing as well.

Pick-up teeth on the radial bevel gear allow the N2 speed sensor to measure High Pressure Compressor rotor speed.

Safety Conditions

CAUTION

MAKE SURE THE LAYSHAFT IS CLEAR OF THE ANGLE GEARBOX BEFORE REMOVAL


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
O RING
SPLINE UPPER DRIVE GEAR
CIC ATTACHMENT FLANGE
LAY SHAFT COVER
CRANK PAD
COMPRESSOR INTERMEDIATE CASE (CIC) REAR VIEW

MGB OIL SEAL & ACCESSORY DRIVES

Purpose:

The drive seals prevent oil loss from the MGB at the interface between the gearbox and the component drive.

Location:

The seals for the Hydraulic Pump, IDG, IFPC and de-oiler are located on their respective drive pads on the MGB.

Description:

The drive oil seals are spring-loaded, carbon-face seals that are paired with a seal runner.

The seal has an integrated oil jet to cool the seal runner.

The seal housing assembly is held in place by a retaining ring and has a puller groove used to remove the assembly.

The seal runner and carbon seal are replaced together. Packings are used between the seal housing and MGB housing, and between the runner and drive shaft.

Operation:

1. The drive seals create a seal between the static, spring-loaded carbon face and the rotating seal runner.

A wave spring behind the carbon face forces it to seat against the runner.

The runner sealing surface is highly polished and parallel, creating a tight seal.

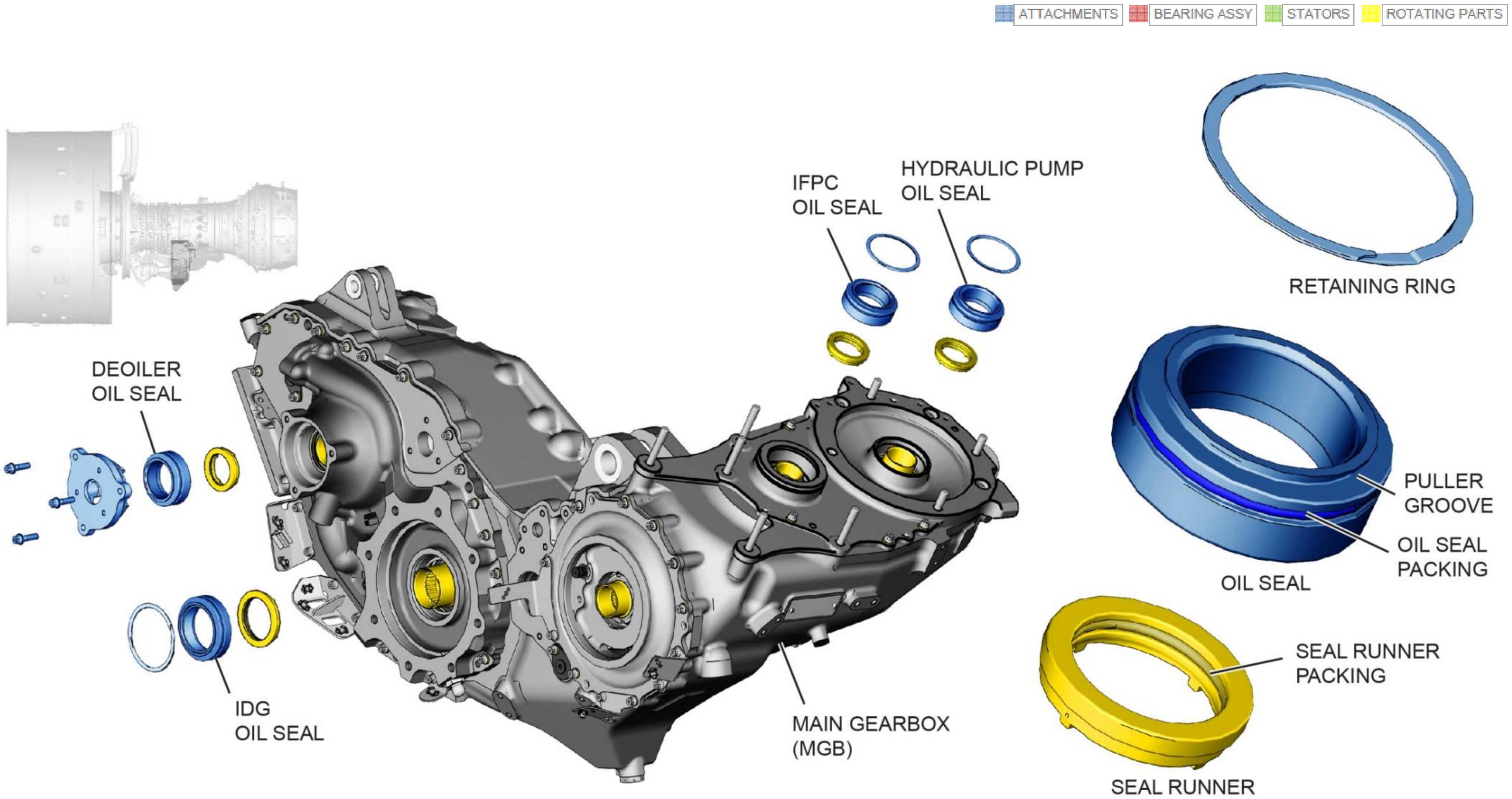
2. The runner is installed on the MGB shaft that drives the component.

The shaft turns the runner that seals against the carbon, creating an effective seal that eliminates oil leakage from the MGB. Oil is sprayed on the runner to reduce its operating temperature.

Safety Conditions

CAUTION

HANDLE THE OIL SEAL WITH CARE. DO NOT SCRATCH OR DAMAGE THE CARBON SEALING SURFACE DURING HANDLING OR INSTALLATION. IF YOU SCRATCH OR DAMAGE THE CARBON SEALING SURFACE, YOU CAN NOT REPAIR IT. THE SEAL ASSEMBLY MUST BE REPLACED.


ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
IFPC
OIL SEAL
HYDRAULIC PUMP
OIL SEAL
RETAINING RING
DEOILER
OIL SEAL
PULLER
GROOVE
OIL SEAL
PACKING
OIL SEAL
SEAL RUNNER
PACKING
IDG
OIL SEAL
MAIN GEARBOX
(MGB)
SEAL RUNNER

BORESCOPE ACCESS

The borescope procedure permits visual inspection of internal gas path parts without the need for engine disassembly.

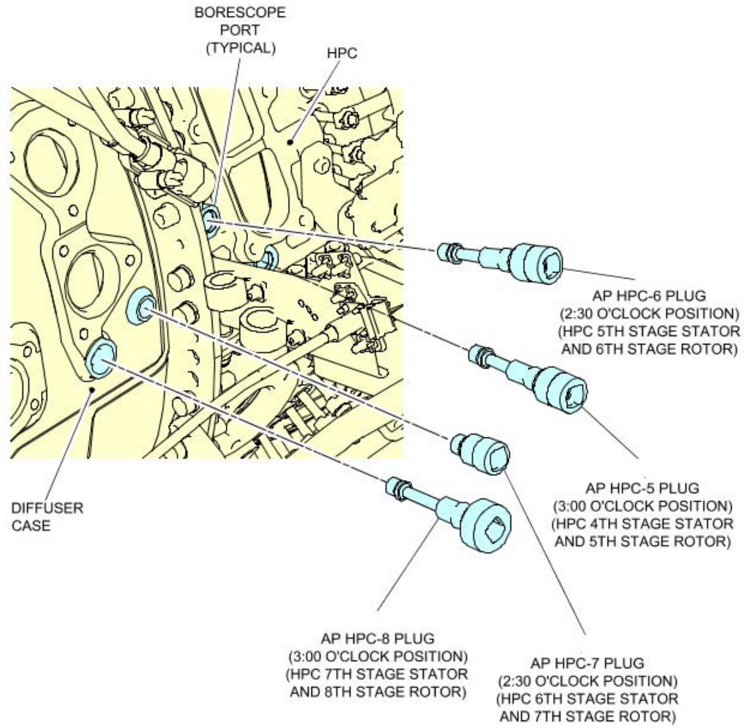
A borescope probe is inserted through access ports to inspect parts for damage, cracks, wear, and missing material. Igniter plug locations can also be used for access once the plugs are removed.

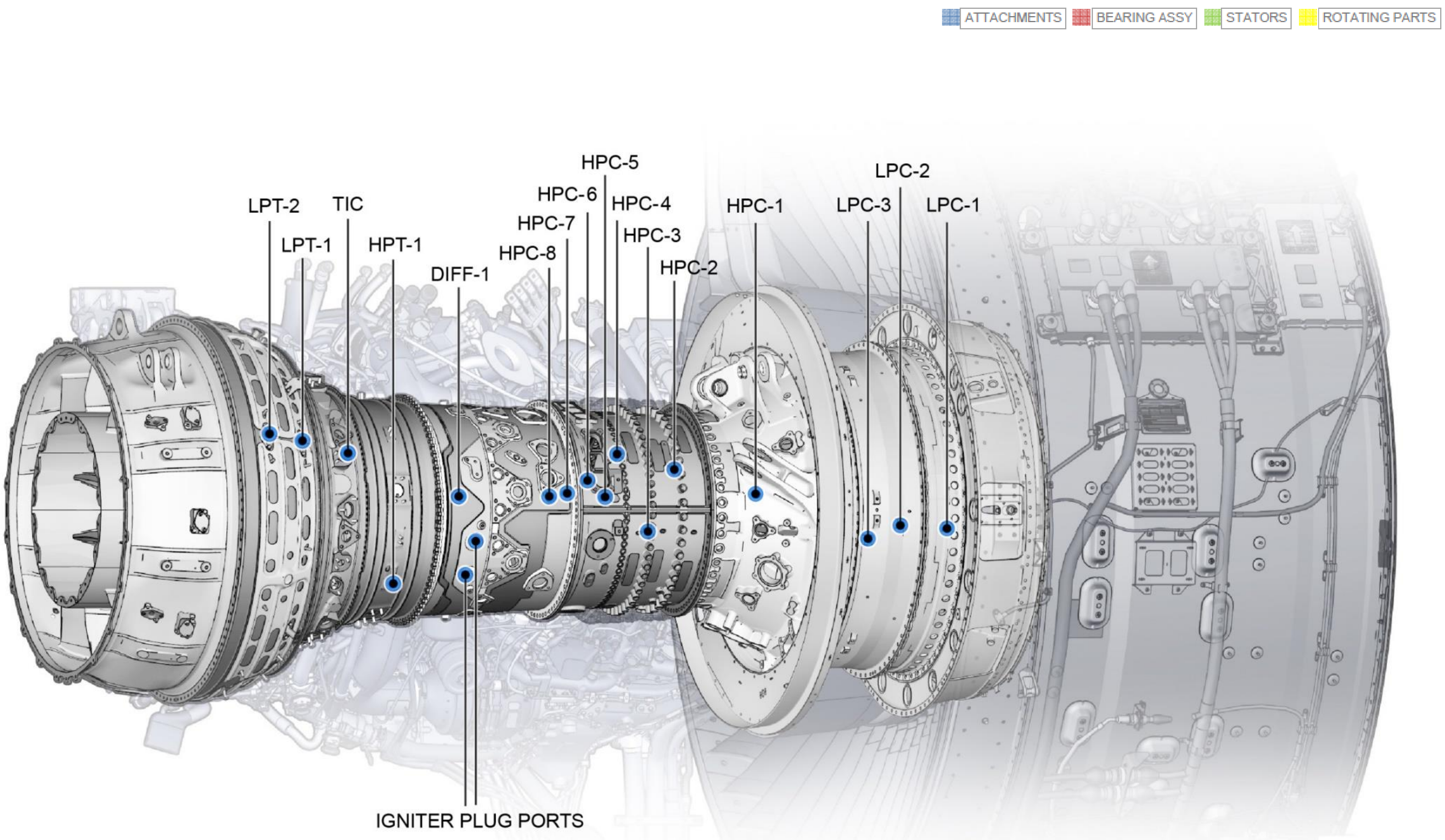
WARNING: DO THE BORESCOPE INSPECTION IN AN AREA WHICH HAS PROTECTION FROM THE WEATHER. IF A BORESCOPE INSPECTION IS DONE IN WET CONDITIONS, USE SUFFICIENT PROTECTION TO PREVENT POSSIBLE ELECTRICAL SHOCK TO THE OPERATOR OR DAMAGE TO THE EQUIPMENT. AN ELECTRICAL SHOCK CAN KILL A PERSON OR CAUSE A BAD INJURY.

CAUTION: MAKE SURE THE TEMPERATURE IN THE ENGINE IS LESS THAN 150 DEG.F (65.6 DEG.C) BEFORE YOU INSTALL THE FLEXIBLE BORESCOPE IN THE ENGINE. IF THE ENGINE IS HOTTER THAN 150 DEG.F (65.6 DEG.C), THE FLEXIBLE BORESCOPE CAN MELT. WARNING: DO THE BORESCOPE INSPECTION IN AN AREA WHICH HAS PROTECTION FROM THE WEATHER.

IF A BORESCOPE INSPECTION IS DONE IN WET CONDITIONS, USE SUFFICIENT PROTECTION TO PREVENT POSSIBLE ELECTRICAL SHOCK TO THE OPERATOR OR DAMAGE TO THE EQUIPMENT. AN ELECTRICAL SHOCK CAN KILL A PERSON OR CAUSE A BAD INJURY. CAUTION: MAKE SURE THE TEMPERATURE IN THE ENGINE IS LESS THAN 150 DEG.F (65.6 DEG.C) BEFORE YOU INSTALL THE FLEXIBLE BORESCOPE IN THE ENGINE. IF THE ENGINE IS HOTTER THAN 150 DEG.F (65.6 DEG.C), THE FLEXIBLE BORESCOPE CAN MELT.

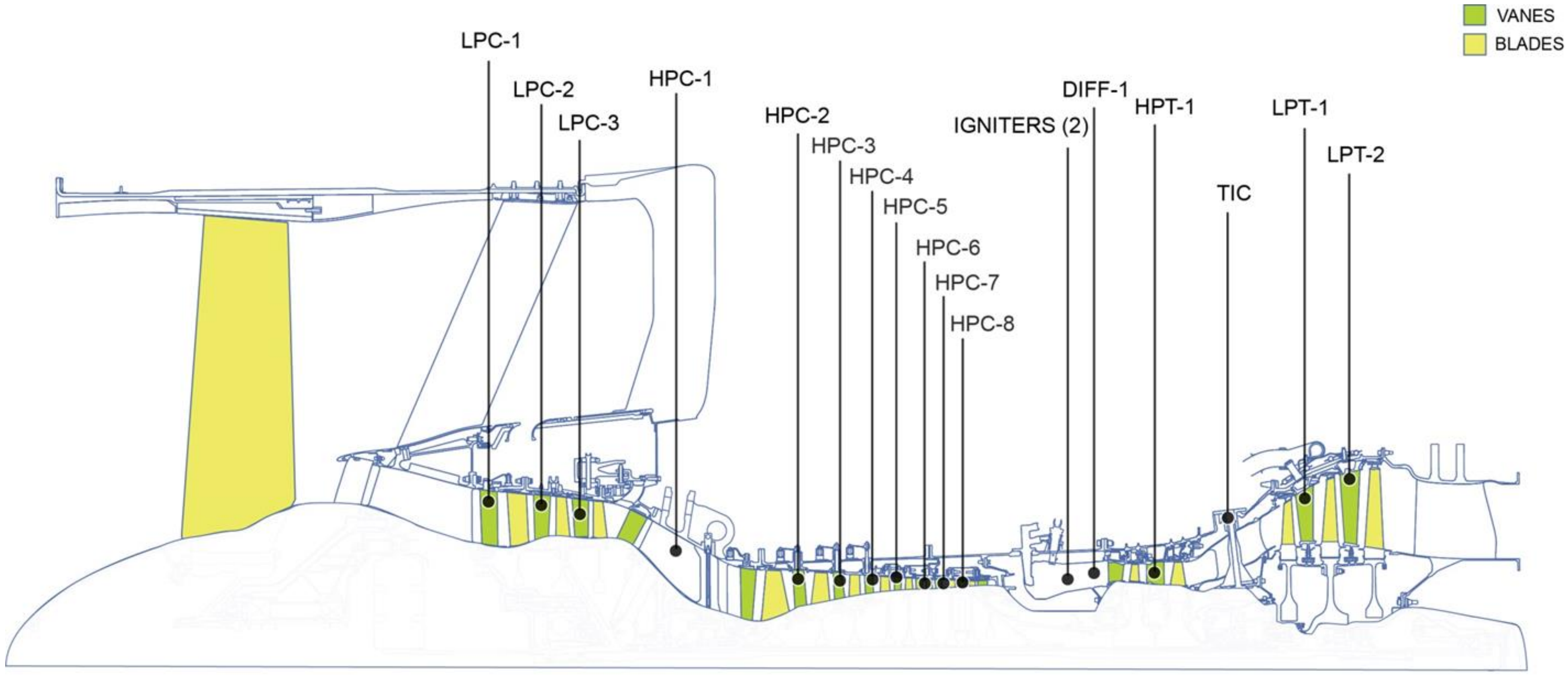
TYPICAL BORESCOPE PORTS




ATTACHMENTS
BEARING ASSY
STATORS
ROTATING PARTS
HPC-5
LPC-2
HPC-6
HPC-4
LPT-2
TIC
HPC-1
LPC-3
LPC-1
HPC-7
HPC-3
LPT-1
HPT-1
HPC-8
HPC-2
DIFF-1
IGNITER PLUG PORTS

AP	Location	Inspection Area
LPC-1	3:30	LPC inlet vanes and 1st Stage vanes, 1st Stage LPC blades
LPC-2		LPC 1st Stage vanes and 2nd Stage blades
LPC-3		LPC 2nd Stage vanes and 3rd Stage blades
HPC-1	3:00	HPC inlet guide vanes and 1st Stage blade
HPC-2	2:00	HPC 1st Stage stator and 2nd Stage blade
HPC-3	3:30	HPC 2nd Stage stator and 3rd Stage blade
HPC-4	1:30	HPC 3rd Stage stator and 4th Stage blade
HPC-5	3:00	HPC 4th Stage stator and 5th Stage blade

AP	Location	Inspection Area
HPC-6	1:30	HPC 5th Stage stator and 6th Stage blade
HPC-7	3:00	HPC 6th Stage stator and 7th Stage blade
HPC-8	1:30	HPC 7th Stage stator and 8th Stage blade
Igniter plug ports	3:30/4:00	Combustion chamber inner and outer liner, fuel nozzles and 1st Stage nozzle guide vanes
DIFF-1	3:00	
HPT-1	4:00	HPT 1st Stage rotor, 2nd Stage stator, and 2nd Stage blade
TIC	2:00	HPT 2nd Stage blade rear LPT 1st Stage blade front
LPT-1		LPT 1st Stage rotor, 2nd Stage stator, and 2nd Stage blade
LPT-2		LPT 2nd Stage rotor, 3rd Stage stator, and 3rd Stage blade


VANES
BLADES
LPC-1
LPC-2
LPC-3
HPC-1
HPC-2
HPC-3
HPC-4
HPC-5
HPC-6
HPC-7
HPC-8
IGNITERS (2)
DIFF-1
HPT-1
TIC
LPT-1
LPT-2

INTENTIONALLY BLANK