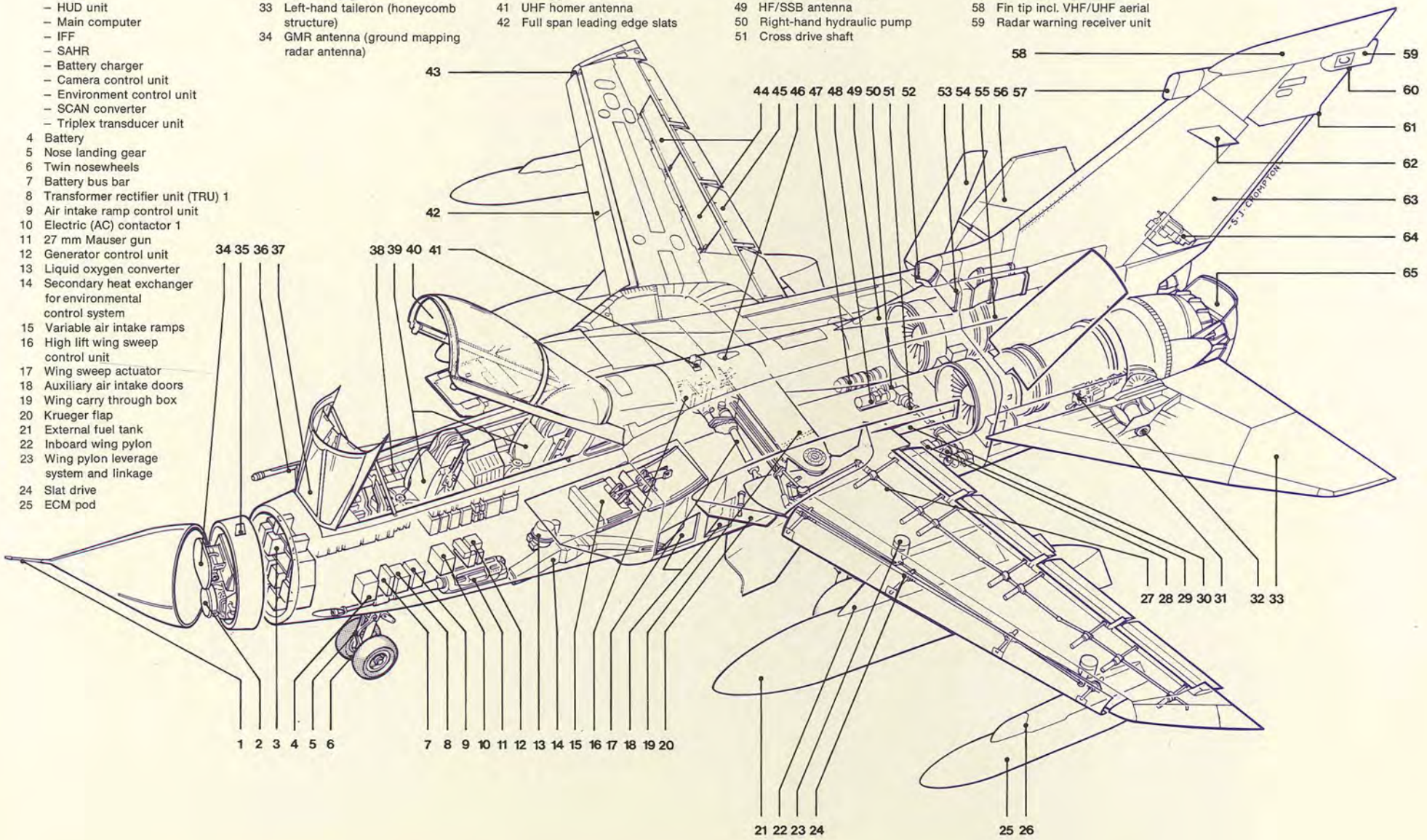
TORNADO MAINTAINABILITY

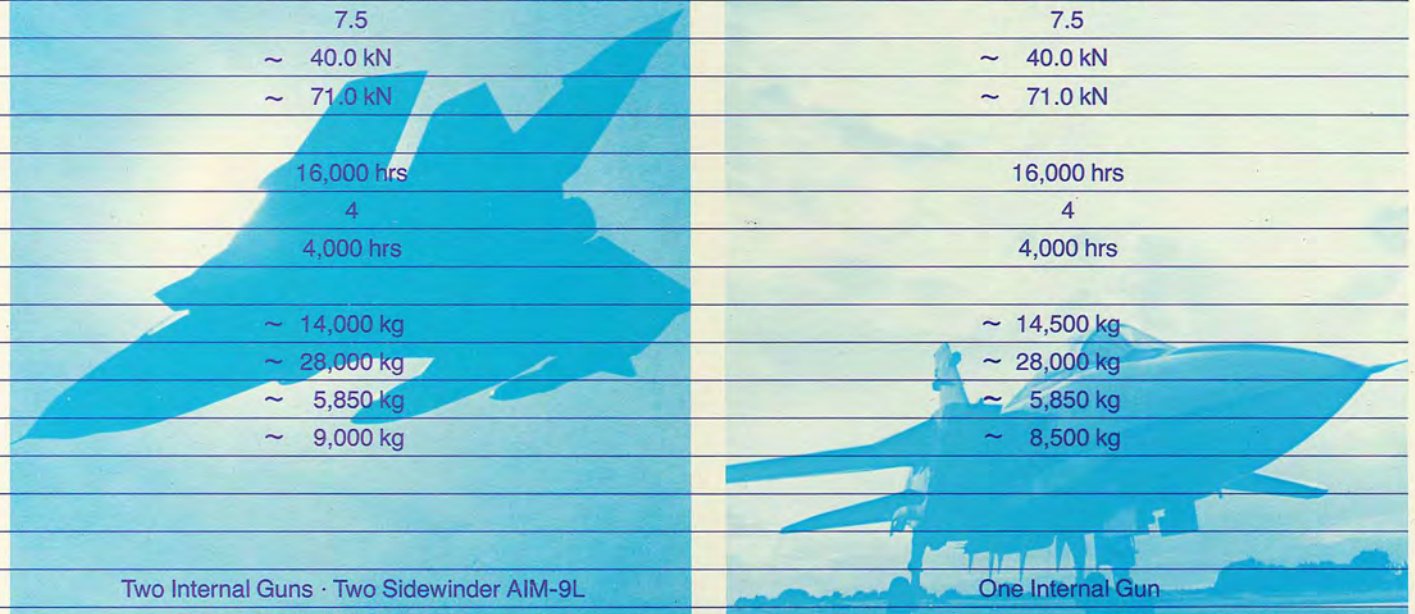
Overall Layout

1 Radome pitot static probe
2 TFR radar antenna
3 Forward avionic bay including:
– Inertial navigation platform
– Air data computer
– Doppler
– Tacan
– HUD unit
– Main computer
– IFF
– SAHR
– Battery charger
– Camera control unit
– Environment control unit
– SCAN converter
– Triplex transducer unit
4 Battery
5 Nose landing gear
6 Twin nosewheels
7 Battery bus bar
8 Transformer rectifier unit (TRU) 1
9 Air intake ramp control unit
10 Electric (AC) contactor 1
11 27 mm Mauser gun
12 Generator control unit
13 Liquid oxygen converter
14 Secondary heat exchanger for environmental control system
15 Variable air intake ramps
16 High lift wing sweep control unit
17 Wing sweep actuator
18 Auxiliary air intake doors
19 Wing carry through box
20 Krueger flap
21 External fuel tank
22 Inboard wing pylon
23 Wing pylon leverage system and linkage
24 Slat drive
25 ECM pod
26 Outboard wing pylon
27 Flap drive
28 Left-hand generator
29 Left-hand hydraulic pump
30 Inflatable air bags
31 Taileron actuator
32 Taileron spigot
33 Left-hand taileron (honeycomb structure)
34 GMR antenna (ground mapping radar antenna)
35 IFF antenna
36 Inflight refuelling probe, extended (detachable)
37 Windscreen (hinged)
38 Right-hand instrument panel, pilot
39 Martin Baker MK 10A ejection seats
40 Canopy
41 UHF homer antenna
42 Full span leading edge slats
43 Obstruction light
44 Spoilers
45 Full span double slotted trailing edge flaps
46 Upper anti-collision light
47 APU (auxiliary power unit)
48 Right-hand generator
49 HF/SSB antenna
50 Right-hand hydraulic pump
51 Cross drive shaft
52 Primary heat exchanger inlet
53 Primary heat exchanger for environmental control system
54 Airbrakes
55 RB 199 engine
56 Right-hand taileron
57 Radar warning receiver unit
58 Fin tip incl. VHF/UHF aerial
59 Radar warning receiver unit
60 Obstruction/navigation light
61 Fuel vent
62 ILS G/S and localizer aerial
63 Rudder
64 Rudder actuator
65 Thrust reverser bucket (deployed)



Data Summary

	IDS	ADV
General Dimensions		
Overall Length	16.72 m	18.10 m
Wing Span Swept	8.60 m	8.60 m
Wing Span Unswept	13.91 m	13.91 m
Height	5.95 m	5.95 m
Performance		
Maximum Level Speed	Mach 2.2/800 kt	Mach 2.2/800 kt
G Attained to Date	7.5	7.5
Thrust per Engine	~ 40.0 kN	~ 40.0 kN
Reheated Thrust per Engine	~ 71.0 kN	~ 71.0 kN
Structure		
Design Fatigue Life	16,000 hrs	16,000 hrs
Scatter Factor	4	4
Minimum Service Life	4,000 hrs	4,000 hrs
Masses		
Operational Mass Empty	~ 14,000 kg	~ 14,500 kg
Max. Take-off Mass	~ 28,000 kg	~ 28,000 kg
Max. External Fuel	~ 5,850 kg	~ 5,850 kg
Max. Payload	~ 9,000 kg	~ 8,500 kg
	Two Internal Guns · Two Sidewinder AIM-9L	One Internal Gun
	Automatic Terrain Following Radar	Two Sidewinder AIM-9L · Four Sky Flash Missiles
	Ground Mapping Radar	Foxhunter Multiple Target Track While Scan Radar
	Doppler Radar · IN · SAHR · ADC	IFF Interrogator
	Kalman Filter Processing · LASER	Data Link



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Introduction

The TORNADO weapon system was designed and developed to be maintained with minimum cost and down-time servicing.

The combined expertise of major aircraft and equipment manufacturers of three European nations together with dedicated Air Force maintainability groups has been the major asset in meeting these requirements in all areas of the weapon system.

Scheduled Servicing is minimal, there are few "lifed" components, component removal and replacement times are short; for example, the RB 199 engine can be removed and replaced in-service in under 40 minutes. Armed Turn Rounds are rapid over a wide range of weapons. An exceptionally high Mean Time Between Failure (MTBF) rate has been achieved.

Maintenance time on the aircraft and in the shops has been reduced, also requirements for training and the skill level of personnel are lower. Spares requirements are reduced and special-to-type ground support equipment is minimal for flight line operations. This together with overall savings in maintenance housekeeping, results in an exceptionally low life cycle cost.

TORNADO is in-service with four Air Arms who acclaim the consistently high operational readiness and the relative simplicity in maintenance of this aircraft. TORNADO is three times easier and cheaper to operate than the best of the types it is to replace.

TORNADO IDS in service at the TTTE Cottesmore

Tornado Maintenance Concept

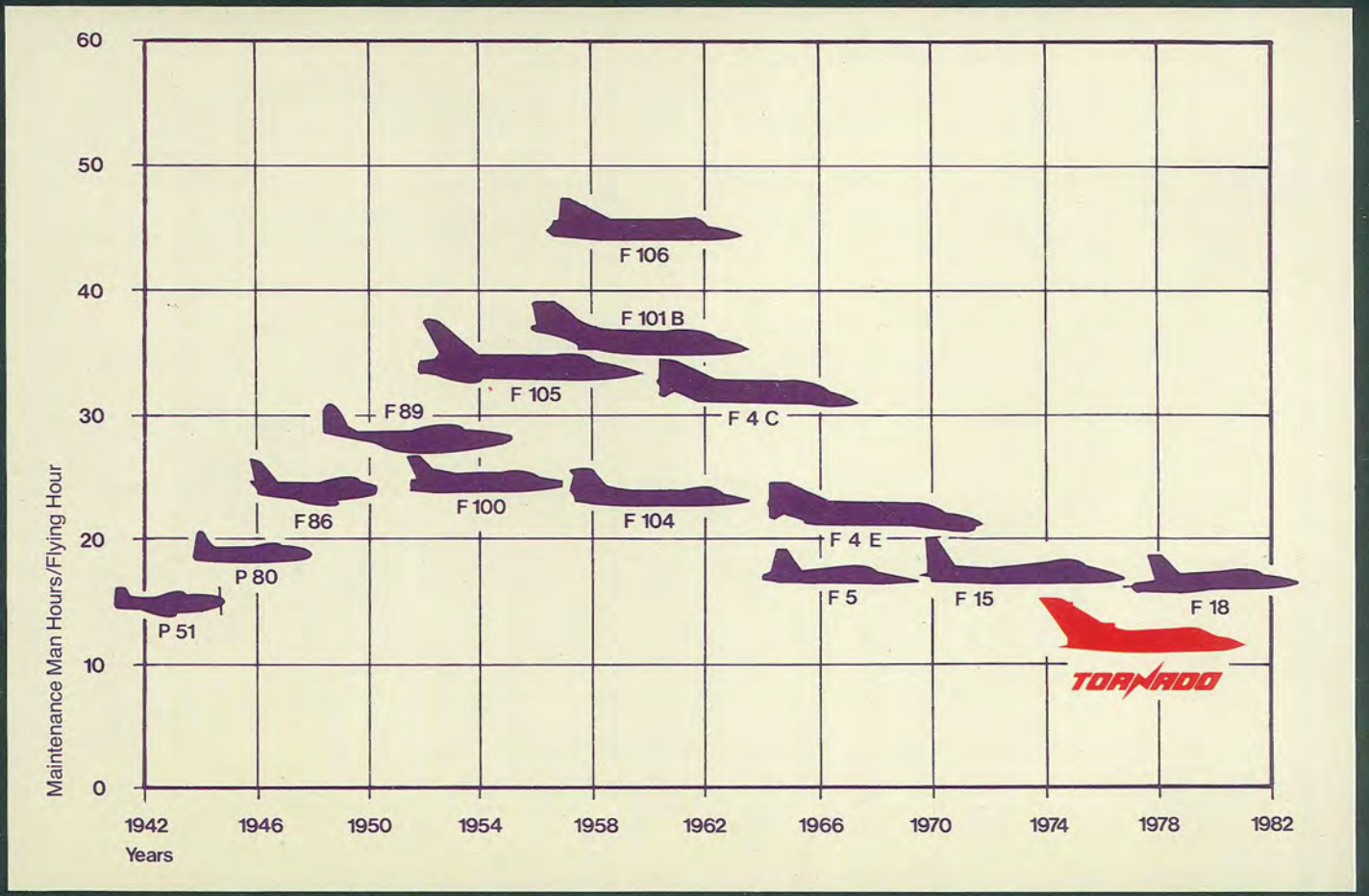
The keystone of TORNADO's maintenance concept is Condition Monitoring Maintenance. Aircraft systems and components are designed to function without the need for inspections or to have hard time limits. Such maintenance on TORNADO provides for corrective action only when an item fails. The concept utilises extensive self-checking fault detection facilities as part of all major systems on the aircraft. Where components have operating safety implications or can cause "expensive to repair" damage, and where condition verification is needed for the few existing lifed items, then certain inspection or servicing is undertaken.

All such inspection or servicing requirements have to be justified and are kept to an absolute minimum, the sum result being minimal scheduled maintenance.

As a contribution to the concept PANAVIA used an advanced electronic data processing system which produced the most cost effective solution on a life cycle basis. This process covered:

- Investigation of maintenance expenditure on scheduled tasks on the weapon system
- Calculation of defect arising rates, maintenance level and skill requirements and the definition of Quality Assurance responsibilities
- Long-term analysis of the expenditure for Personnel and Training, Spare Parts and AGE

Optimisation of maintenance procedures has resulted in very low manhour requirements for scheduled maintenance tasks.



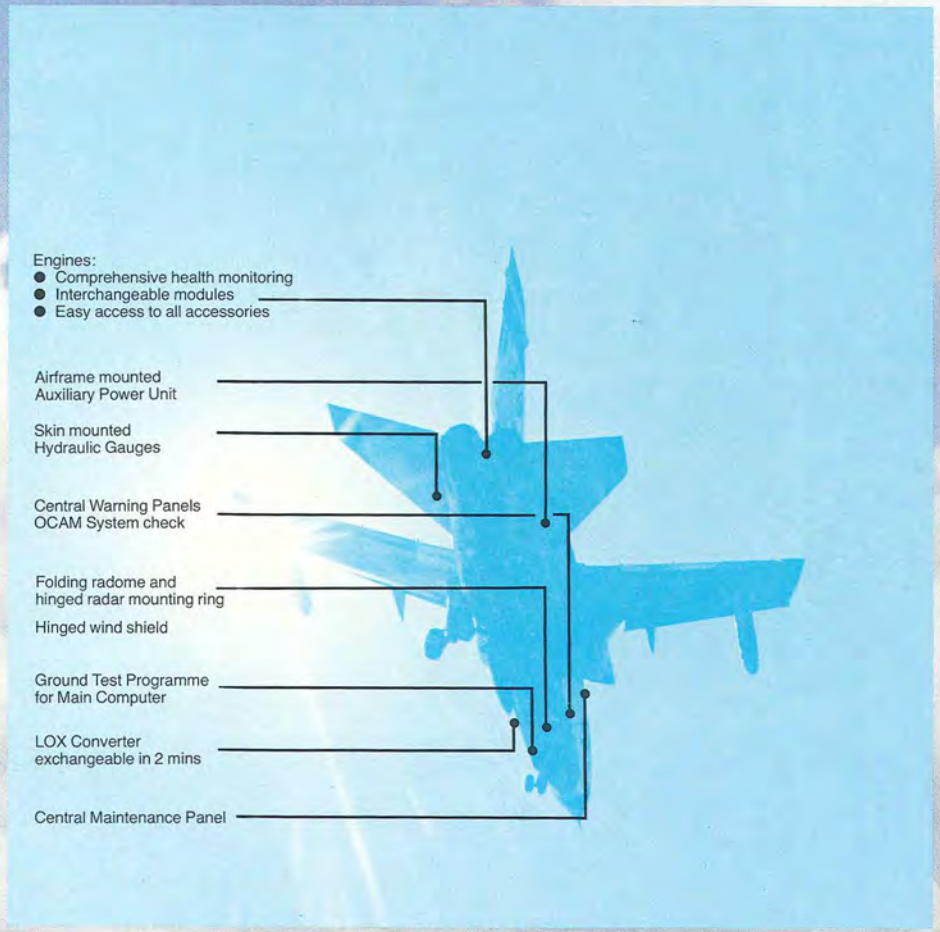
TORNADO leads the trend towards reduced maintenance needs

On and off aircraft scheduled maintenance is less than 4.5 direct Maintenance Man Hours/Flying Hour (MMH/FH) including:

– Pre-Flight Inspection	1 Man 12 mins
– Turn Round	2 Men 12 mins (lapsed time)
– Post-Flight Inspection	2 Men 45 mins (lapsed time)

– Periodic Inspection Requirements at 300, 600, 900 FH

Maintainability



TORNADO's excellent maintainability ensures high operational readiness coupled with minimum down-time maintenance and cost.

The achieved maintainability is featured in depth throughout all weapon system areas and interfaces.

Specific maintainability features are identified in the Systems descriptions. A cross-section of some highlighted features and resulting benefits follows:

Features

- Excellent accessibility with 40 % of the aircraft surface removable for access
- Sub-system equipments are built on a Line Replaceable Unit (LRU) basis with no harmonisation required for the replacement of almost all LRU's
- On-board Check-out and Monitoring (OCAM)
- Test access points on the few LRU's without BITE
- Stringent reliability specifications on all equipment
- Minimum Aerospace Ground Equipment (AGE)
- Automatic Test System (ATS) at Base Second Level
- RB 199 engine features sophisticated health monitoring techniques
- Engine accessories on a modular concept
- Engine removal and replacement in under 40 minutes

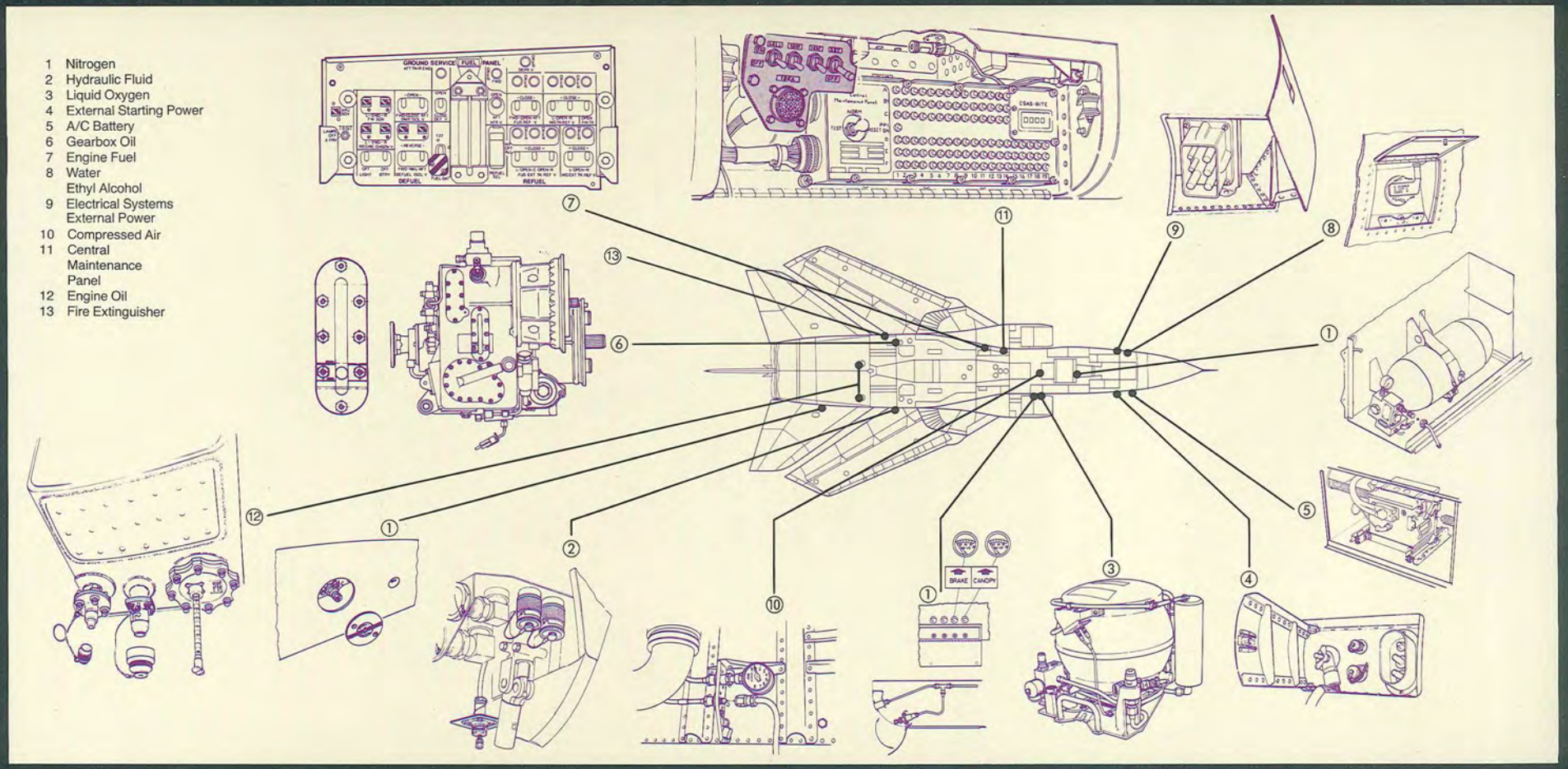
Benefits

- High operational readiness
- Interoperability and flexibility of operation
- Life cycle cost minimised through savings in:

– Overall manpower
– Skill levels of operators
– Training requirements
– Expenditure on spares
– Repair and overhaul
– Support equipment
– Compatible reductions in maintenance administration

TORNADO maintainability features

1 Nitrogen
2 Hydraulic Fluid
3 Liquid Oxygen
4 External Starting Power
5 A/C Battery
6 Gearbox Oil
7 Engine Fuel
8 Water
Ethyl Alcohol
9 Electrical Systems
External Power
10 Compressed Air
11 Central
Maintenance
Panel
12 Engine Oil
13 Fire Extinguisher



Quick and simple servicing speeds up turn round times

Whilst user Air Forces may operate to different maintenance concepts and organisations, TORNADO, with its relative simplicity in maintenance, integrates easily into existing practices. A further advantage is the utilisation of a high degree of standard support equipment and facilities.

Coupled with this the low fuel consumption and the low attrition rate of TORNADO combine to produce the lowest cost of ownership throughout the weapon system life time.

Reliability

Comprehensive test programmes with definitive reliability targets for each system/equipment were initiated during the TORNADO development phase to conform with stringent specifications. In addition, throughout the production phase selected components are subjected to comprehensive reliability demonstrations and Production Reliability Acceptance Tests (PRAT). Each item is required to meet all of the conditions of these acceptance tests before release.

In parallel, Reliability Analysis and Defect Mode Effect Analysis has provided basic data for maintainability predictions and expenditure forecasts for the various support activities. Systematic defect data collection during all phases of rig and flight tests together with inputs from the Air Forces has provided the input data necessary to allow continuous monitoring of the reliability growth.

In-service experience already demonstrates exceptionally high Mean Time Between Failures (MTBF), which projects a Mission Essential success factor of 94 %.

- Fewer parts per system – fewer failures
- Only military preferred parts used
- Electrical and mechanical parts de-rating
- Component burn-in
- Stringent cyclic testing on all actuators
- Extensive use of Defect Mode and Effect Analysis (DMEA)
- Reliability validation through demonstration

Failure Identification

Failure identification and location on TORNADO is achieved with minimum skill levels, minimum manpower and a minimum of AGE, pinpointing defects without ambiguity.

Decreased maintenance workload at the Flight Line results in low overall down-time of the aircraft and enhanced operational capability from Dispersed Operating Bases.

Test and diagnostic facilities utilise airborne and ground based equipment.

Features: (On-Aircraft)

On-Board Checkout and Monitoring Facility (OCAM)

The OCAM facilities does as its title implies. It provides on-aircraft equipment fault detection/location for avionic and certain non-avionic sub-systems as well as providing a monitoring facility of specified in-flight data and sub-system operational performance.

OCAM is achieved by combining a number of facilities which will:

- Detect an LRU/sub-system malfunction
- Indicate that a malfunction has occurred
- Automatically switch to an alternative data source (where applicable)
- Store in-flight data for use in accurately locating defective LRU's
- Provide comprehensive sub-system checks using built-in test facilities
- Provide complete sub-system, system and interface checks using software

OCAM includes:

BUILT-IN TEST EQUIPMENT (BITE)

Detection of malfunctions is achieved by incorporating a self-checking facility into most avionic and certain non-avionic sub-systems which continually validates equipment performance. This is called the CONTINUOUS Built-in Test Equipment (C-BITE). Malfunction indications, triggered by C-BITE, are given visually by lights and displays (accompanied by audio warnings) which define the malfunction.

INTERRUPTIVE BITE is also incorporated. This is initiated manually via the equipment control panel and enhances the detection/location capability of the C-BITE. It is only a ground test facility.

BITE will detect and locate to a single LRU some 80 % of all avionic defects (with a confidence level of 90 %) without the removal of any equipment from the aircraft and without the use of external test equipment.

For the few equipments where BITE is not provided a test point is readily accessible on the LRU.

CENTRAL MAINTENANCE PANEL (CMP)
The serviceability status of defined LRU's either avionic or defined non-avionic is stored on the CMP which has latched indicators. The indicator illuminates and is latched even if the failure is of a transient nature, thereby allowing preventative rectification to be carried out of such failures monitored. The CMP also provides a numerical display for the BITE checkout facilities of the Command and Stability Augmentation System (CSAS), giving an accurate guide to locating a defective LRU.

CENTRAL WARNING SYSTEM (CWS)
Warnings are brought to the crews attention via:

- Front and Rear Cockpit Central Warning Panels (CWP) with Warning Lights
- Audio Warning Signals
- Attention Getters
- HUD Display (Flight Critical)

CRASH RECORDER
The crash recorder digital data equipment stores on magnetic tape aircraft and avionic parameters. In addition a single track of combined aircrew voice is recorded for use on the ground during major incident analysis.

MAIN COMPUTER SOFTWARE
Aside from the Operational Flight Programme (OFP) the Main Computer Software, loaded via the rapid data entry cassettes, includes:

- Ground Test Facility (GTF)

  This is co-resident in the Main Computer with the OFP. It provides an on-ground facility for displaying, on the TV/Tab-Display, specified input data to the Main Computer monitored by the In-flight Monitor (IFM).
  Monitoring is inhibited whilst the aircraft is not in flight. Previous flight data is cleared and restarted ready to record new data when the calibrated airspeed exceeds 100 kts. At the end of a mission the monitored information can be called up by the groundcrew during replay tests.

- External Ground Test Programme (EGTP)

  The EGTP provides an on-ground defect detection and location capability in the avionic sub-systems and Flight Control System (FCS), additional to that provided by BITE. It is loaded into the Main Computer in place of the OFP and constitutes a full maintenance tool with plain language read-out on the TV/Tab-Display of the sub-system and interface status.

Features: (Off-Aircraft)

Automatic Test System (ATS)

ATS has been designed to meet 2nd level (Intermediate) testing requirements for most of the LRU's. The system is capable of extension to deeper maintenance levels.

ATS comprises four Automatic Test Equipment (ATE) stations for the testing and fault diagnosis of TORNADO LRU's down to module level.

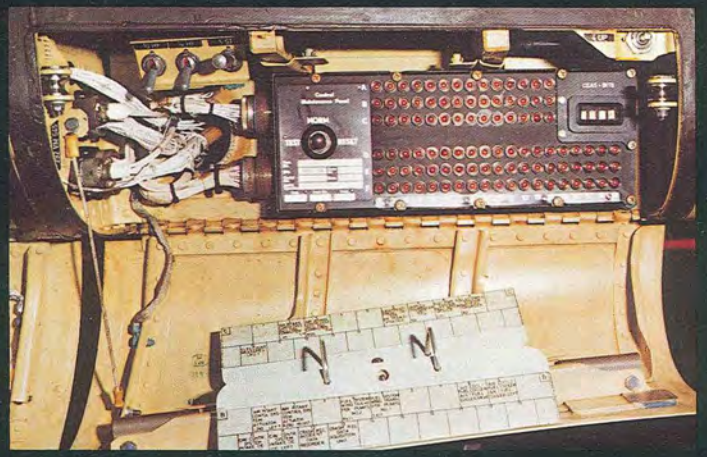
The stations are:

- Low Frequency and Digital
- Video
- Radio Frequency
- Microwave

The National Operator's servicing policy will dictate the combinations of ATE required: these will normally be situated at a main operating base for operation by medium skill level Air Force personnel at 2nd (Intermediate) maintenance level. Such is the flexibility of the ATS that any of the ATE sta-

Automatic Test System Station

Central Maintenance Panel



tions can be operated independently from each other thus enabling an operator to adopt his own needs and maintenance concept.

Special-to-Type Test Equipment (STTE)

As a full alternative to ATS a range of STTE is available for comparable, but mainly manual testing of LRU's and Modules.

The design of TORNADO is such that operators can utilise certain ranges of STTE from existing national holdings.

OCAM Maintenance Features

- Intensive monitoring by OCAM ensures that equipment failure identification and location is achieved with:
  - Minimum manpower
  - Minimum skill levels
  - Minimum AGE
  - Minimum "down and turn-around time"
- Defects are pinpointed with optimum accuracy in minimum time scales
- Continuous and Interruptive BITE for most avionic and selected non-avionic sub-systems
- BITE enables 80 % of all failures to be detected/located to a particular LRU
- The Maintenance Panel utilises latched malfunction indications (light emitting diodes) each associated with one item of equipment, system or part of a system
- Test access points readily accessible on the few LRU's without BITE
- Ground Test Facility (GTF) co-resident in the MC with the OFP
- External Ground Test Programme (EGTP). A complete maintenance tool for avionic subsystems and FCS with plain language read out on TV Tabular Display

STTE Maintenance Features

- Full alternative (manual) to ATS
- Certain STTE can be utilised from operator's national resources

ATS Maintenance Features

- Fully automatic
- 4 Independent Automatic Test Equipments:
  - Low frequency and digital (computers, interface units etc.)
  - Video (displays, waveform generators etc.)
  - Radio frequency (communication)
  - Microwave (radar, Doppler etc.)
- Selection of individual ATE to suit customer concept
- Rapid test and location of fault of most avionic LRU's to module/printed circuit board level
- Operation by Air Force personnel at 2nd (Intermediate) Level
- International Standard Test Language (ATLAS)

Aerospace Ground Equipment

One of the significant operational advantages of TORNADO is its general independence from special-to-type ground support equipment on the Flight Line and operation away from Base. The on-board Auxiliary Power Unit (APU) provides engine starting, electrical and hydraulic power for ground purposes. The extensive use of Built-In Test Equipment (BITE) in the aircraft's system permits rapid check-outs, fault diagnosis and defect location.

At deeper levels of maintenance and repair of TORNADO and its equipment, however, a range of Aerospace Ground Equipment (AGE) is required which has been developed to rigid criteria (including NATO Standardisation) through the expertise of major European aircraft manufacturers and suppliers together with service experts of four Air Arms.

TORNADO AGE is unique in its flexibility. The way in which it integrates with national operational and maintenance concepts, existing national holdings of AGE and Government Furnished Equipment (GFE), provide a high degree of cost effectiveness to the operator.

- APU provides engine starting and electrical/hydraulic power. Extensive use of BITE keeps AGE to a minimum at Flight Line Level
- Rigid criteria for AGE selection and design:
  - Minimum AGE consistent with operational availability
  - Rugged and reliable
  - Ease of operation and maintenance
  - Air transportability
  - Use of Système Internationale (SI) units
- Comprehensive list of:
  - General AGE
  - Avionic AGE
  - Repair and Overhaul AGE

Comprising:

- Tools
- Covers
- Blanks
- Handling Equipment
- Loading Equipment
- Power Trolleys
- Test Equipment

for all levels of maintenance

- AGE list items completely flexible to suit individual Air Force maintenance concepts and requirements and achieving cross servicing among participating countries throughout

Interoperability

Whilst TORNADO maintenance and operational concepts may vary between Operators, design of the weapon system from the onset with emphasis on compliance with STANAGS and Military Specifications, has enabled the prime aims of standardisation and interoperability to be met.

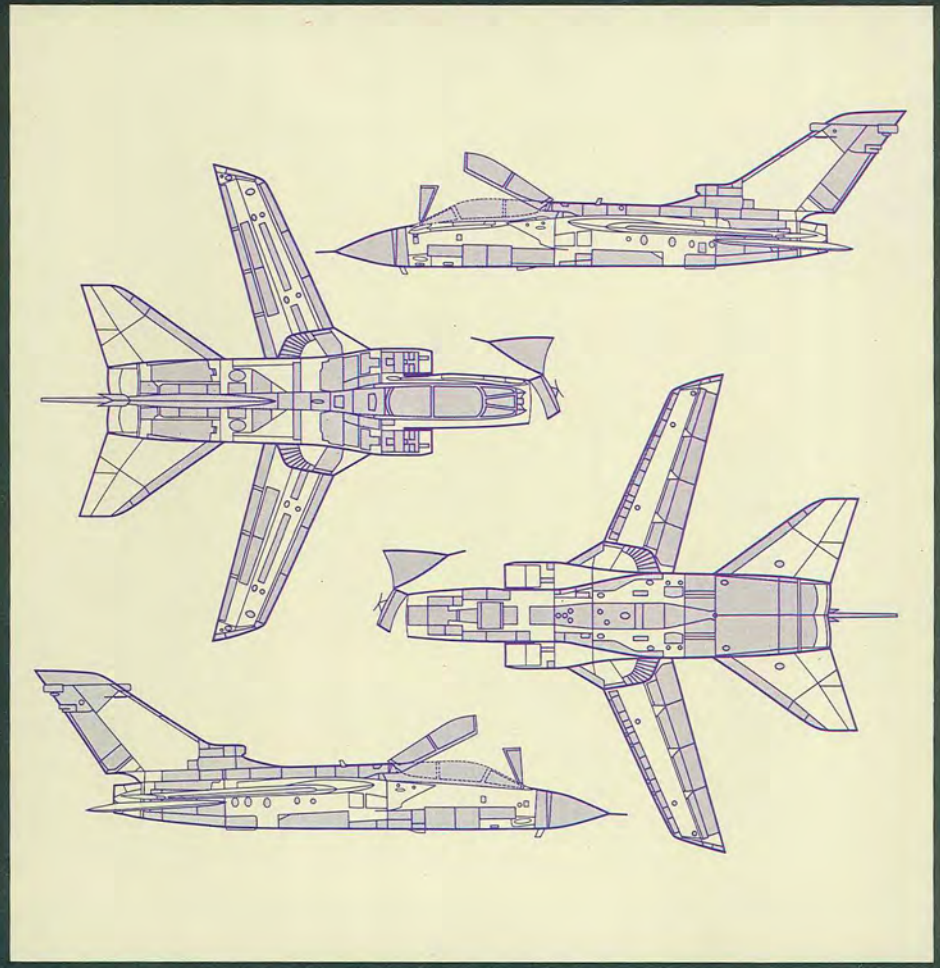
In use by four of Europe's leading Air Arms, variants of TORNADO are fully interoperable in respect of replenishing, Flight Line servicing and rectification. Re-arming with a wide range of stores is catered for in the aircraft Stores Management System (SMS).

TORNADO's use of the absolute minimum of AGE facilitates Flight Line operations and operation away from Base. An on-board Auxiliary Power Unit (APU) can be started from the aircraft battery, powering all systems so that the aircraft can be checked out by BITE without need for ground power trolleys or diagnostic equipment. All replenishment points comply with NATO standards. The ammunition box has its own built-in hoist system and so is also independent of AGE.

It will meet cross-servicing requirements at NATO Bases and will not require special-to-type maintenance facilities additional to those defined by SHAPE criteria for NATO Bases.

Accessibility

Over 350 easily removable panels provide access for maintenance work



Good maintainability demands good accessibility. This has been met on TORNADO.

Note the features:

- Approximately 40 % of the external surface area consists of access panels including:
  - 52 panels with quick release latches (quick access for speedy turn-arounds, role changes, etc.)
  - 88 panels with Calfax fasteners (1 1/2 turns to open/close)
  - 23 panels with shoot bolts
  - 193 panels with torque set screws (for access to long MTBM items and skin panel removal)
- For easy maintenance, particularly on the Flight Line, access to equipment and replenishment is via panels using quick release fasteners
- Most equipment installations are accessible from the ground with maximum working height of 1.7 m
- Most access panels and doors are replaceable without trimming (including main landing gear doors)
- Skin gauges and transparent sight gauges in many systems
- Hinged windscreen allows quick and easy access to the back of the pilot's instrument panel
- Radome is doubly hinged:
  - Opening the complete radome allows easy access to the forward avionic bay
  - Opening the middle section allows access to the front and rear of the radar
- Large engine bay doors with shoot bolts for easy access to engines and accessories
- Engine health monitoring access points allow extensive inspection all from the underside of the engine