MANUTENÇÃO AERONÁUTICA

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Manutenção de Aeronaves

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MÓDULO I

1. **Fiabilidade**

    - **Programa de Manutenção**
    - **MSG-3**

An aircraft receives about 17 man-hours of maintenance for every flight hour.

That may seem excessive - unless you are the one riding in that aircraft.

So – the questions are:

- Do aircraft really break all that often?
- Do they need that much maintenance?
- Are they that unreliable?

THE ANSWER IS NO

Definition Of Reliability

- **Reliability is the probability that a system will perform its intended function without failure, during a specified period of time, under specified operating conditions.**
  - Reliability Has A Precise Engineering Meaning
  - Reliability Measures How Well A System Is Performing
  - Reliability Measures Success

$$R(t) = Pr\{T > t\} = \int_t^\infty f(x)\,dx$$

where $f(x)$ is the failure probability density function and t is the length of the period of time.

Reliability is concerned with four key elements of this definition

1 - Reliability is a probability. This means that failure is regarded as a random phenomenon that the likelihood to occur varies over time according to the given probability function.

2 - Reliability is predicated on "intended function:" Generally, this is taken to mean operation without failure.

3 - Reliability applies to a specified period of time. In practical terms, this means that a system has a specified chance that it will operate without failure before time t.

4 - Reliability is restricted to operation under stated (or explicitly defined) conditions. This constraint is necessary because it is impossible to design a system for unlimited conditions.

Inherent Reliability

- Inherent Reliability Measures The Success Of The Design
- An Effective Maintenance Program Will:
  - Measure Reliability Decline With Age
  - Rebuild Reliability Through Proper Maintenance Actions
  - Establish An Economic Balance Between The Cost Of Maintenance And The Cost Of Reliability Decline

A Maintenance Program Maintains The Inherent Reliability; Maintenance Does Not Increase The Reliability Of The Design

No design is going to be failure free forever.
Inherent reliability is the best reliability a given design can expect.
This is the target reliability that a maintenance plan strives to maintain.

Failure Characteristics
Failure Definitions

- **Failure**
  - **An Unsatisfactory Condition**
- **Functional Failure**
  - **An Actual Failure Where An Item (Or The Equipment Containing It) No Longer Meets A Specified Performance Standard**
- **Potential Failure**
  - **A Detectable Condition Which Indicates A Functional Failure Is About To Happen**

Failure Detection

Evident Function ⟷ **Hidden Function**

Evident Function

- Crew Member Must Be Able To Detect the Failure:
  - Location
  - Time
- Observer Must Be Able To Recognize:
  - Potential Failure
  - Functional Failure

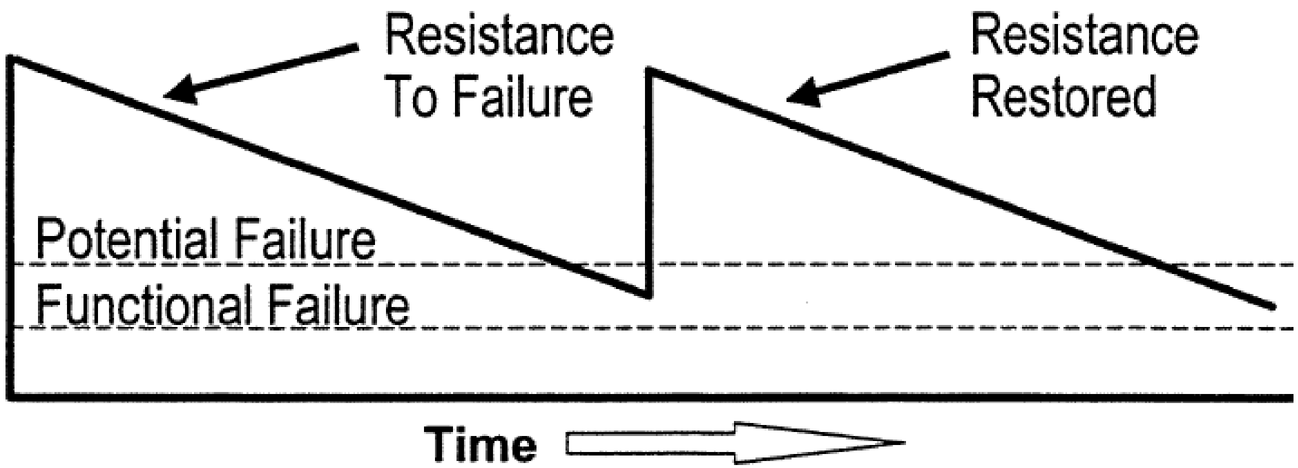
Hidden Function

- Normally Not Operating So Capability Is Not Known
- Normally Working But Gives No Indication Of Failure

Both Have Potential For Safety And Economic Problems

Failures In Simple Items

- **Simple Items Have Few Failure Modes**
- **Resistance To Failure Decreases With Time**
- **Potential Failure Occurs When The Resistance Reaches A Threshold**
- **Functional Failure Occurs When Resistance Cannot Support The Load**
- **Maintenance At The Potential Failure Level Prevents The More Costly Functional Failure**



Proper maintenance at the desired time restores the resistance to failure, and the process can start all over again, with the resistance to failure decreasing once again.

Failures In Complex Items

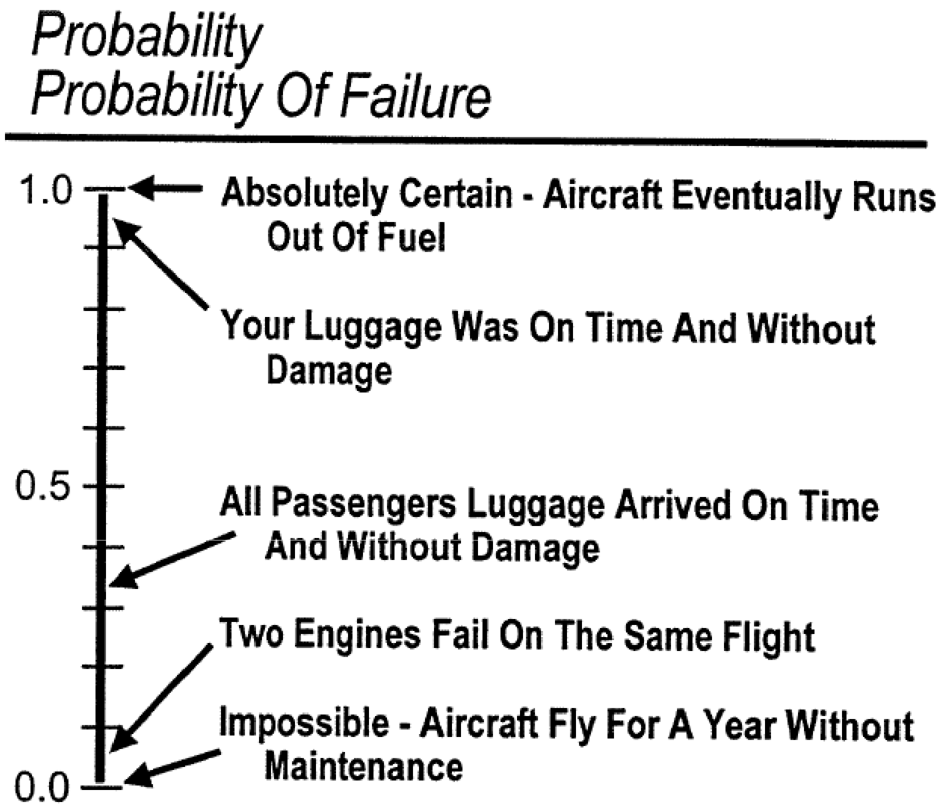
- Many Failure Modes
- Each Mode Has Different Failure Conditions
- Most Probable Or Dominant Failure Mode Produces Most Failures
- Each Mode Has Different Failure Aging
- Combination Of Many Failure Modes Produces Random Time To Failure
- Safety Related Failures Need:
  - Detection Of Potential Failure, Or Redesign

Items with a high potential for safety problems need a very good opportunity for detection, or the item should be redesigned. Serious safety related failures should not be tolerated.

Consequences Of Failure

- Safety
  - Involves Injury Or Loss Of Equipment
- Operations
  - Aircraft Delays Or Flight Restrictions
- Other
  - Do Not Impact Safety Or Operations

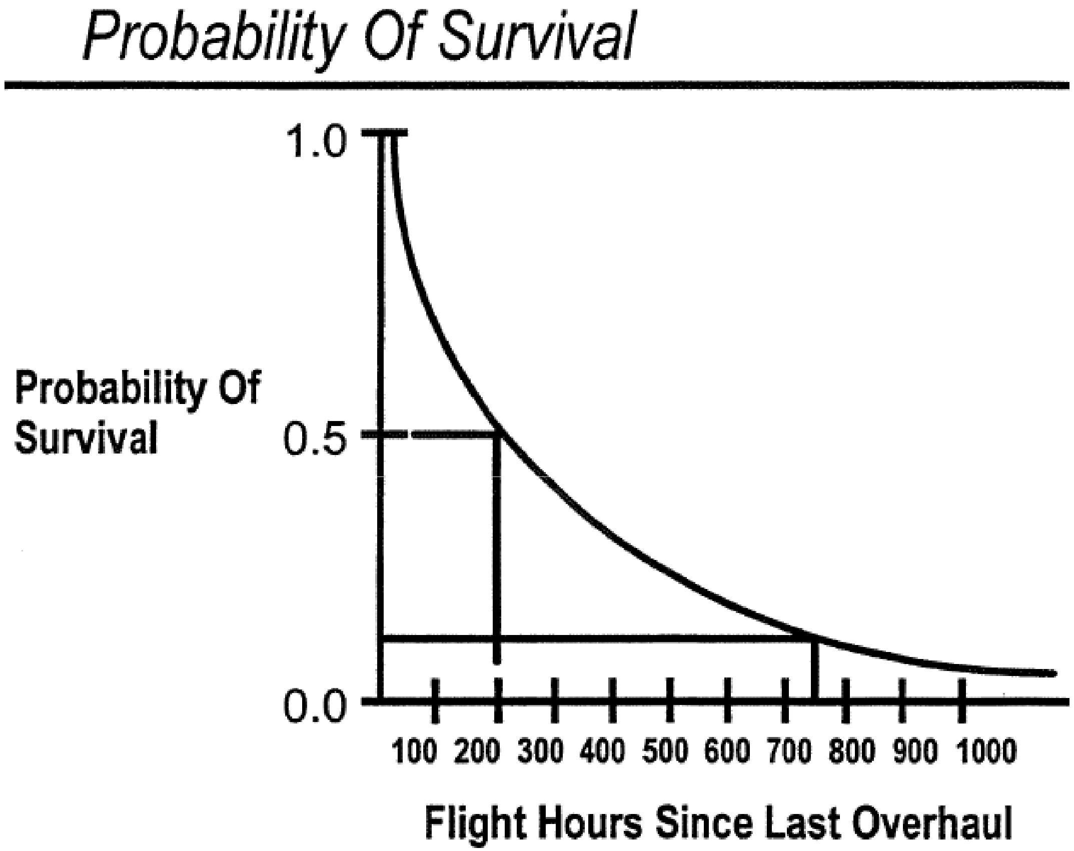
The Consequence Of Failure Determines The Activity Of The Maintenance Program



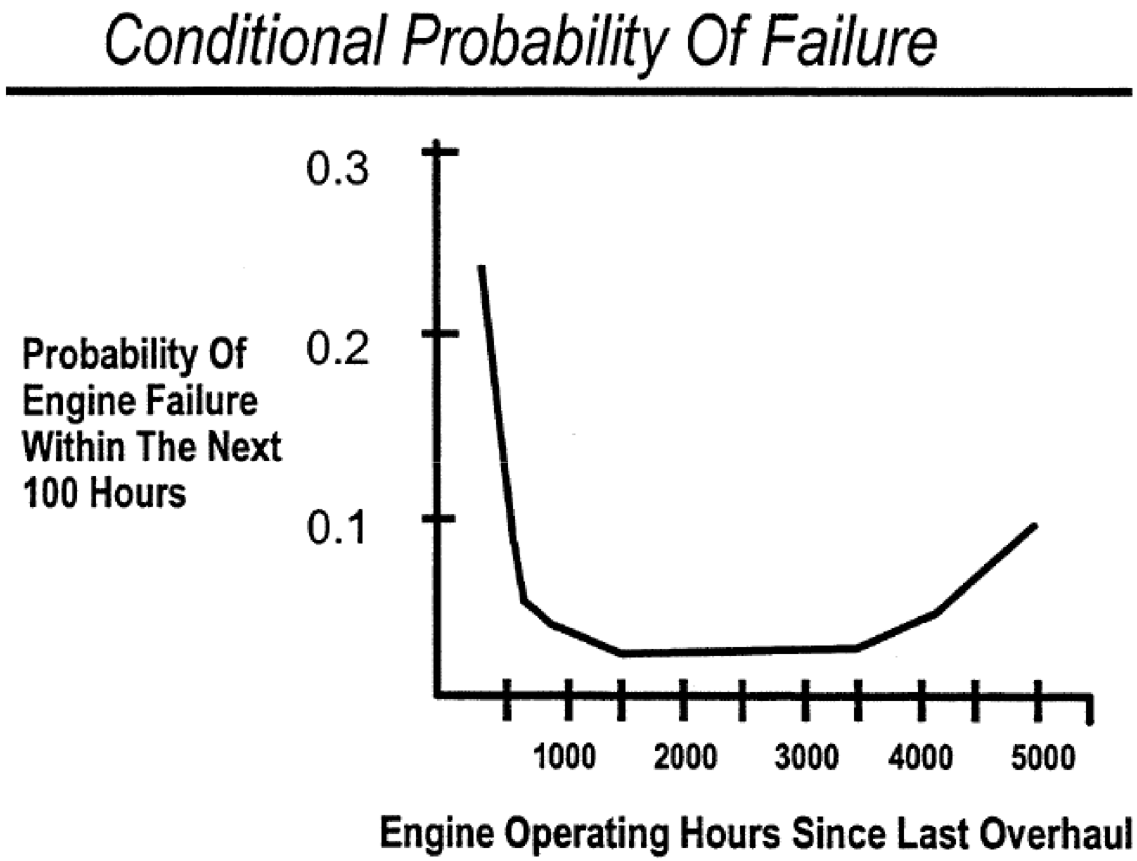
(Probability Measures How Likely Something Is To Happen)

The probability scale ranges from zero to one (0 - 1.0). This is equivalent of 0% to 100%. 0% would represent something totally impossible. An example could be for an aircraft to try and fly for a year without maintenance. That is impossible. That would have a 0% probability.

100% would represent something that is absolutely certain to happen. An example could be for an aircraft to run out of fuel. This is bound to happen if the aircraft flies long enough without refueling.

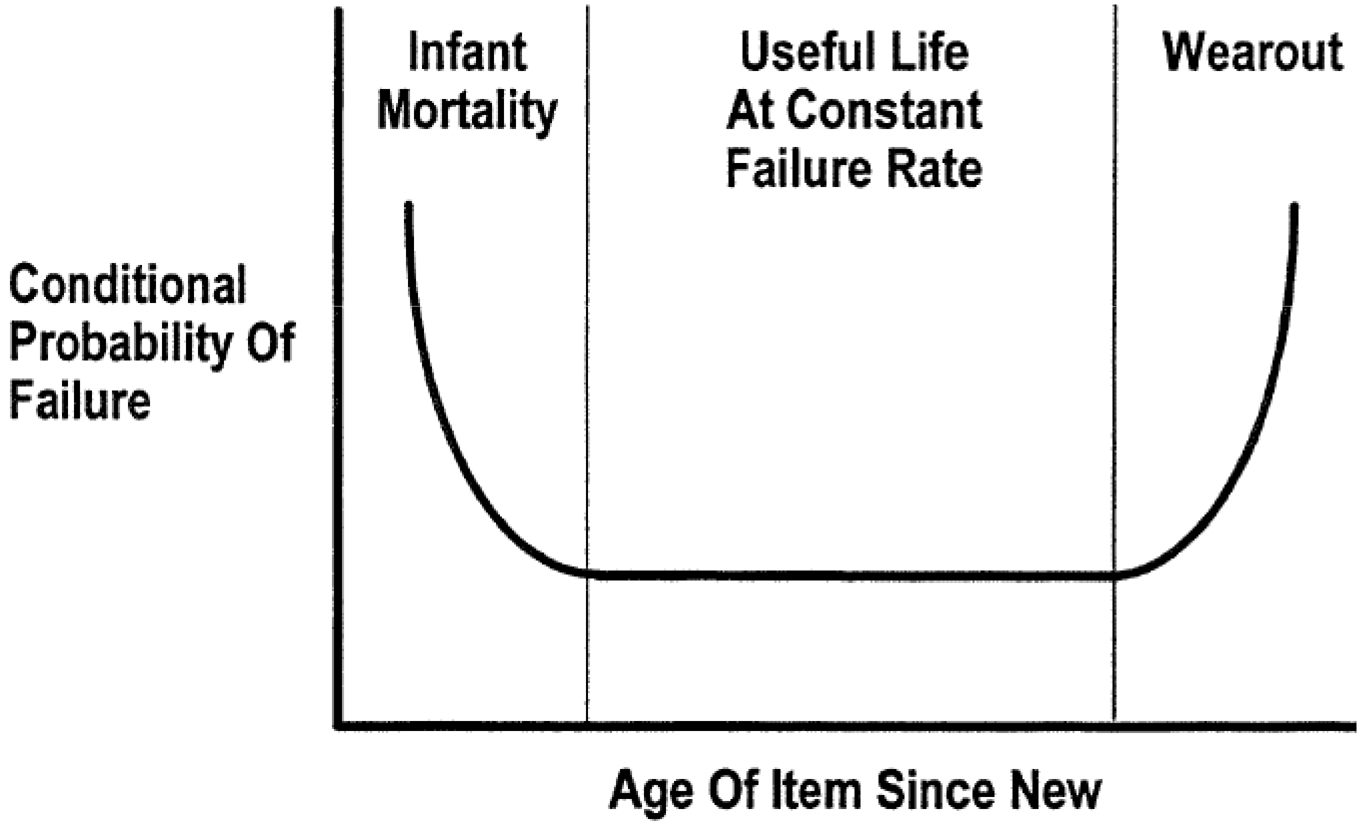


The probability of survival is an extension of the definition of probability over time. This is closely related to the definition of reliability.



The probability of failure can change over time. Conditional Probability is the term used to describe this phenomena.

Failure Patterns Versus Age



Infant Mortality

- Very High Initial Probability Of Failure
- Reasons For Early Failures Could Be:
  - Defects In Materials
  - Defects During Assembly
  - Defects In The Design Process
  - Defects From Rough Handling
  - Defects From Improper Storage
  - Improper Installation
- Elimination May Be Cost Effective
  - Simple Changes May Eliminate Or Reduce Problem
  - Cost Of Changes Less Than Cost Of Replacements

Useful Life Of Constant Failure Rate

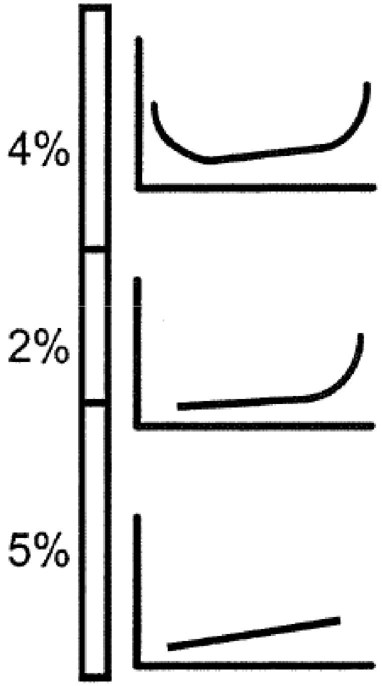
- Period Of Random Time To Failure For Complex Items
- Predictable For A Fleet Workload In Terms Of:
  - Maintenance Actions
  - Supply Support
- Lowest Failure Rate Approaches Inherent Reliability

Wear Out

- **Conditional Probability Of Failure Increases With Age**
- **Increased Probability Of Failure Caused By:**
  - **Physical Changes From Operation Usage**
  - **Chemical Changes From Time Or Temperature**
- **Policy To Remove Before Wear Out Not Often Cost Effective**

The maintenance plan should consider the wearout, but this does not mean that a removal policy is always cost effective. For items which do not have significant effects if they fail, early removal only wastes available life.

Reliability Patterns Versus Component Age (1 of 2)



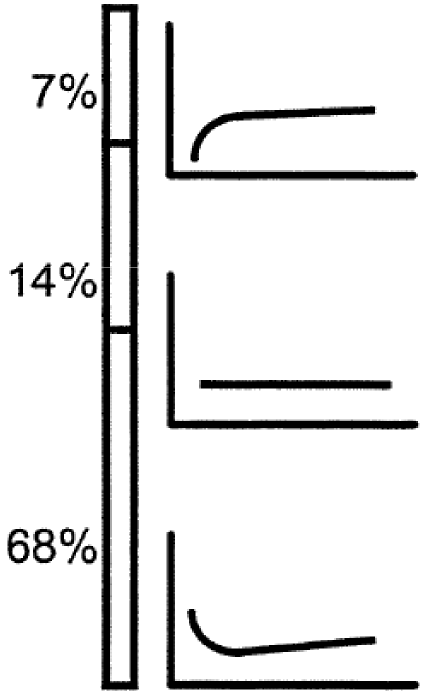
The Bathtub Curve: Infant Mortality, Followed First By A Constant Or Gradually Increasing Failure Probability And Then By A Pronounced "Wear Out" Region. An Age Limit May Be Desirable, Provided A Large Number Of Units Survive To The Age At Which Wear Out Begins.

Constant Or Gradually Increasing Failure Probability, Followed By A Pronounced Wear Out Region. Once Again, An Age Limit May Be Desirable (This Curve Is Characteristic Of A/C Reciprocating Engines).

Gradually Increasing Failure Probability, But With No Identifiable Wear Out Age. It Is Usually Not Desirable To Impose An Age Limit In Such Cases (This Curve Is Characteristic Of A/C Turbine Engines).

11% Might Benefit From A Limit On Operating Age

Reliability Patterns Versus Component Age (2 of 2)



Low Failure Probability When The Item Is New Or Just Out Of The Shop, Followed By A Quick Increase To A Constant Level.

Constant Probability Of Failure At All Ages (Exponential Survival Distribution).

Infant Mortality, Followed By A Constant Or Very Slowly Increasing Failure Probability (Particularly Applicable To Electronic Equipment).

89% Cannot Benefit From A Limit On Operating Age

Programas de Manutenção – Maintenance Programs

<table>
<tr><th><1960</th><th>1961-1993</th><th>A Actualidade</th></tr>
<tr><td>Hard Time (H.T.)</td><td rowspan="2">MSG analysis

Reliability Centered Maintenance (R.C.M.)

Aircraft Condition Monitoring System (A.C.M.S.)

Engine Condition Monitoring (E.C.M.)

On Board Maintenance Systems (OMS)</td><td>Hard Time (H.T)

On Condition (O.C)

Condition Monitoring (C.M.)</td></tr>
<tr><td>Overhaul and the zero hours urban legend</td><td>Sampling Programs

Corrosion Prevention and Control Program

Aging Programs</td></tr>
</table>

FIABILIDADE - RELIABILITY

1961 - FAA/Industry Reliability Program

1968 - MSG-1 Handbook — Maintenance Evaluation and Program Development

1970 - MSG-2 — Airline/Manufacturer Maintenance Planning Document

1972 - EMSG (European)

1980 - MSG-3 — Maintenance Program Development Document

1988 - MSG-3 Rev 1

1993 - MSG-3 Rev 2

FIABILIDADE - RELIABILITY

MSG-1; MSG2; EMSG; MSG-3

MSG-1 (1968): Maintenance Steering Committee develops a decision logic for scheduled maintenance development that achieve safety and reliability at minimum cost. This logic diagram was used to develop scheduled maintenance program for B747. Overhaul and On-Condition concepts were used.

MSG-2 (1970): ATA Task Force revises MSG-1 to make it applicable to any aircraft. Introduction of a new maintenance process called Condition Monitoring. Used to develop the initial maintenance programs for L-1011 and DC-10.

EMSG (1972): The Association of European Airlines creates a European version. Used to develop the initial maintenance programs for the A300 and Concorde.

MSG-3 (1980): ATA Task Force (Regulators, aircraft & powerplant manufacturers, airlines and US Navy) creates improvement on MSG-2 to address shortcomings found. Integrates the advances achieved from RCM.. New MSG-3 logic addresses :

(a) further reduction in cost to offset fuel price increases;
(b) Increased complexity of aircraft equipment;
(c) FAR 25.571 new design rules for the use of damage-tolerance;
(d) Further enhancement of manufacturer/operator partnership through the MRB process. Used to develop the initial maintenance programs for 757, 767, A310, and A320.

MSG-3 Rev.1 (1988): ATA Task Force revises MSG-3 to make it more user friendly. Operating Crew monitoring is deleted. Used to develop the initial maintenance programs for 777, MD11, and A340.

MSG-3 Rev.2 (1993): ATA Task Force revises MSG-3 to provide additional clarification and guidelines on development of Corrosion Prevention and Control Programs.

HARD TIME – ON CONDITION – CONDITION MONITORING

The MSG-1 philosophy was based on the theory that all aircraft and their components reach a period when they should be “Zero Timed” or “Overhauled” and be restored to new. MSG-2 created a new analytic approach to maintenance using 3 control processes: Hard Time, On Condition, and Conditioning Monitoring.

Hard Time Limits: A maximum interval for performing maintenance tasks. These intervals usually apply to overhaul, but also apply to the total life of the part or unit.

On Condition Repetitive inspections or tests to determine the condition of units or systems, comprising; Servicing, Inspect, Testing, Calibration, Replacement

Condition Monitoring Applies to items that have neither Hard Time limits nor On Condition maintenance as their primary maintenance process.
Condition Monitoring is accomplished by appropriate means available to an operator for finding and resolving problem areas. The means can range from notices of unusual problems to special analysis of a unit's performance.

Maintenance Philosophies

MSG-2: Process oriented, analyzes failure modes from the part level up. Results in control methods of Hard Times, On Condition Tasks and a large quantity of Condition Monitored items requiring intensive record keeping. The On Condition Tasks consist of Servicing, Inspect, Testing, Calibration and Replacement.

RCM (1978): United Airlines, commissioned by the DOD, develops a methodology for designing maintenance programs based on tested and proven airline practices. RCM addressed MSG-2 shortcoming and uses Task oriented logic to select maintenance tasks. Used extensively in Military Organizations and in the development of the NASA's space shuttle maintenance program. Provided the basis for MSG-3

MSG-3: Task oriented, analyzes system failure modes from a system level or top down. Results in maintenance tasks which are performed for safety, operational, or economic reasons, involving both preventive maintenance which is performed before failure occurs (and is intended to prevent failure), as well as failure finding tasks. The tasks consist of Lubrication/Servicing, Operational/Visual, Inspection/Functional, Restoration, and Discard which are generated through MSG-3 logic analysis.

FIABILIDADE - RELIABILITY

The MSG-2 logic analysis results in scheduled tasks that fit into Hard Time or On Condition maintenance. If no task resulted from the analysis, the item goes to Condition Monitoring

	PREVENTIVE MAINTENANCE CAN INREASE RELIABILITY	PREVENTIVE MAINTENANCE CANNOT INCREASE RELIABILITY
MALFUCNTION CAN AFFECT SAFETY	ENSURES SAFETY (OC or HT)	REQUIRES DESIGN CHANGE
MALFUNCTION CANNOT AFFECT SAFETY	IMPROVES ECONOMICS (OC or HT)	NO VALUE (CM)

Razões da Evolução – Evolution Reasons

- Operating Costs

- Frequent Inspections Not Always Reduce Failure Rate

- Hard Time Maintenance Originates More Problems

- Complexity in design has resulted in a new approach to failure prevention

- More effective reliability methods are used to collect data for maintenance program development and design analysis

FIABILIDADE - RELIABILITY

Development of Maintenance Programs has progressed from ensuring Safety and Reliability by renewing parts to scheduling more cost effective tasks to the airplane to ensure continued serviceability until the next inspection period tasks.

Cost: All operating costs have escalated but as a percentage, maintenance costs have dropped 50% over the last 30 years.

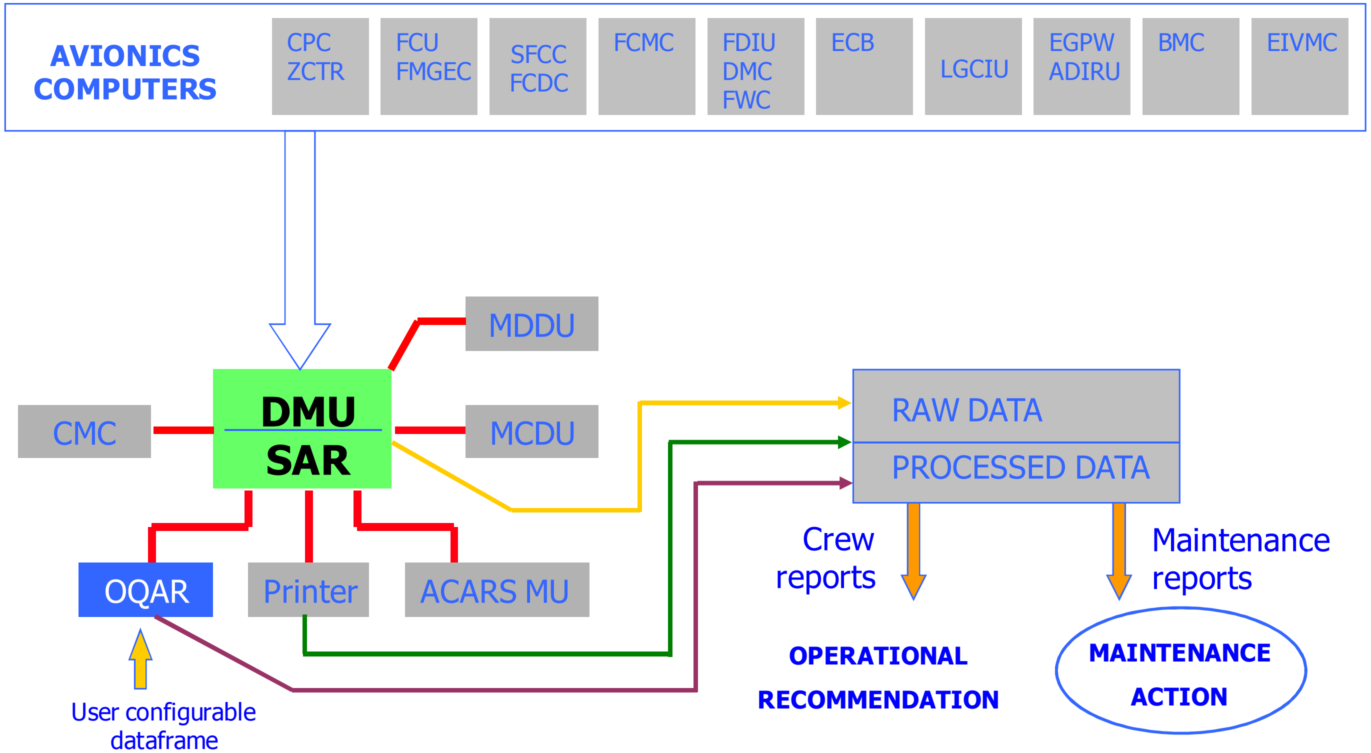
Technology: Maintenance Programs can take dramatic advantage of developments in design, systems and materials.

Reliability: Understanding reliability patterns for complex equipment has driven requirements for maintenance tasks.

Today's Process using MSG-3 analysis: The industry standard is to use the MRB Process with MSG-3 decision logic.

Disciplined Approach: The current process ensures that all significant systems and structures are analyzed in a consistent manner and tasks only selected if they are applicable and effective at lowest cost. Very few Hard Times.

Aicraft Condition Maintenance System (A.C.M.S.)



The complexity of the on-board systems and of the operational methodology is so high nowadays that it is impossible to investigate adequately an aircraft system problem without Flight Data Recorder information obtained through the ACMS

ECM – Engine Condition Monitoring

Motores são monitorizados em todos os voos

Análise de dois pontos em cada voo

Ponto de Take-off – Esforço de motores

Ponto de Cruzeiro Estável

Comparação com os motores de referência – Base Line

Avaliação da degradação dos motores

Programa de ECM (SAGE – System for the Analysis of Gas Turbine Engines) automáticamente produz os resultados da tabela a seguir:

FIABILIDADE - RELIABILITY

REPORT ID: CRDATA

GE ENGINE CONDITION MONITORING PROGRAM SAGE V4.1.0 - MAR 2001

CRUISE PERFORMANCE DATA - FROM 01/01/1980 TO 02/25/2002

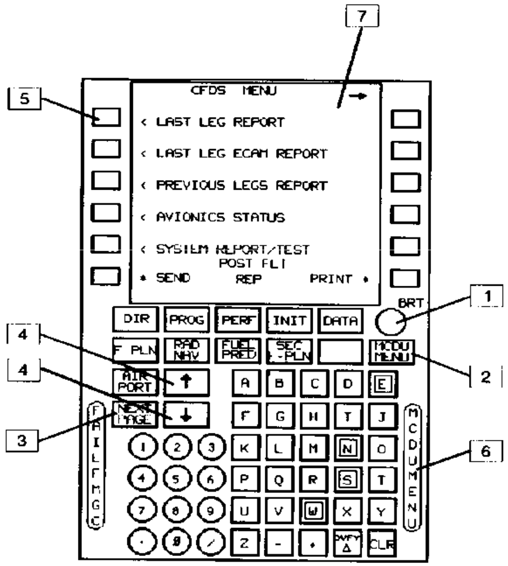
REPORT DATE: 02/25/2002
PAGE: 1

AIRCRAFT ID	AIRCRAFT TYPE	ENG POS	SERIAL NUMBER	ENGINE TYPE	INSTALL DATE	N1 MOD	THRUST RATING	TCC TMR	CONFIG	CONTROL	SELECTOR
CSTOD	A340-300	1	740323	CFM56-5C3/F	010419	5	0.0	0			
		2	740320	CFM56-5C3/F	000829	3	0.0	0			
		3	740296	CFM56-5C3/F	010508	5	0.0	0			
		4	741389	CFM56-5C3/F	011030	6	0.0	0			

FLIGHT DATA																RAW DEVIATIONS					-MAX CONT--		
DATE/ GMT	TAT	ALT	MACH	ENG BLD 1234	A/C PK 123	ISO VLV LRC	ADP 1 2	N1	OIL PRES	FUEL FLOW	VSV	N2	EGT	N1K	BLEED RATIO	DOP	FF (%)	VSV ( )	N2 (%)	EGT (C)	EGT MAR	N2 MAR	ALT CTR
020702-1	-32.5	37990	0.807	1111	***	0**	* *	88.00	45	3322	-0.80	92.2	722	95.63	1.04	-18	-0.1	-9.99	-0.4	-3.2	-999	-9.9	1
1414-2								88.00	46	3393	-1.20	92.3	711	95.63	1.04	-17	2.0	-9.99	-0.3	-14.2	-999	-9.9	0
-3								88.00	45	3300	-1.50	92.1	728	95.63	1.02	-17	-0.7	-9.99	-0.5	3.2	-999	-9.9	0
-4								88.00	50	3254	-1.30	92.1	703	95.63	1.02	-12	-2.1	-9.99	-0.5	-21.8	-999	-9.9	0
020802-1	-16.5	32990	0.820	1111	***	0**	* *	90.13	49	4279	-0.60	94.8	767	95.09	1.00	-16	0.3	-9.99	-0.5	-3.7	-999	-9.9	0
0002-2								90.13	49	4330	-1.00	94.9	752	95.09	1.00	-16	1.4	-9.99	-0.4	-18.7	-999	-9.9	0
-3								90.13	48	4255	-1.20	94.7	763	95.09	1.02	-17	-0.3	-9.99	-0.7	-8.0	-999	-9.9	0
-4								90.12	52	4160	-1.00	94.8	741	95.08	1.02	-13	-2.5	-9.99	-0.5	-29.9	-999	-9.9	0
020802-1	-34.5	38990	0.800	1111	***	0**	* *	86.63	42	3038	-0.50	91.4	710	94.53	1.02	-20	0.0	-9.99	-0.6	1.1	-999	-9.9	1
1821-2								86.63	44	3122	-1.00	91.5	693	94.53	1.02	-18	2.8	-9.99	-0.5	-15.9	-999	-9.9	0
-3								86.63	43	3023	-1.20	91.4	711	94.53	1.03	-19	-0.5	-9.99	-0.6	1.9	-999	-9.9	0
-4								86.63	49	2996	-1.10	91.5	687	94.53	1.03	-13	-1.4	-9.99	-0.5	-22.1	-999	-9.9	0
020902-1	-18.3	37000	0.820	1111	***	0**	* *	89.23	46	3523	-0.70	94.3	767	94.45	1.24	-19	0.1	-9.99	-0.6	-0.8	-999	-9.9	0
0729-2								89.23	47	3594	-1.10	94.4	751	94.45	1.24	-18	2.1	-9.99	-0.5	-16.8	-999	-9.9	0
-3								89.23	46	3512	-1.20	94.2	768	94.45	1.22	-19	-0.2	-9.99	-0.7	0.6	-999	-9.9	0
-4								89.22	51	3450	-1.10	94.3	743	94.44	1.22	-14	-1.9	-9.99	-0.6	-24.3	-999	-9.9	0
021002-1	-5.8	31000	0.821	1111	***	0**	* *	87.83	51	4187	0.20	95.4	765	90.96	1.14	-15	-0.1	-9.99	-0.4	3.5	-999	-9.9	0
0319-2								87.83	49	4224	0.00	95.4	748	90.96	1.14	-17	0.8	-9.99	-0.4	-13.5	-999	-9.9	1
-3								87.82	48	4140	-0.20	95.3	759	90.95	1.14	-18	-1.2	-9.99	-0.5	-2.4	-999	-9.9	0
-4								87.82	53	4079	0.00	95.4	733	90.95	1.14	-13	-2.6	-9.99	-0.4	-28.4	-999	-9.9	0
021002-1	-29.0	36000	0.819	1111	***	0**	* *	85.56	46	3373	-0.10	91.7	708	92.43	1.14	-16	0.4	-9.99	-0.5	1.3	-999	-9.9	1
0546-2								85.56	47	3426	-0.40	91.8	692	92.43	1.14	-15	1.9	-9.99	-0.4	-14.7	-999	-9.9	0
-3								85.56	46	3344	-0.60	91.7	704	92.43	1.13	-16	-0.5	-9.99	-0.5	-2.5	-999	-9.9	0
-4								85.56	51	3291	-0.40	91.7	680	92.43	1.13	-11	-2.0	-9.99	-0.5	-26.5	-999	-9.9	0
021002-1	-21.0	33000	0.807	1111	***	0**	* *	88.64	49	4094	-0.70	93.8	746	94.30	1.02	-15	0.5	-9.99	-0.5	-0.4	-999	-9.9	0
1237-2								88.64	48	4147	-0.90	93.9	729	94.30	1.02	-16	1.8	-9.99	-0.4	-17.4	-999	-9.9	0
-3								88.65	48	4076	-1.30	93.7	742	94.31	1.00	-16	0.1	-9.99	-0.6	-4.2	-999	-9.9	0
-4								88.65	52	3984	-0.90	93.8	717	94.31	1.00	-12	-2.2	-9.99	-0.5	-29.2	-999	-9.9	0
021102-1	-24.3	38990	0.827	1111	***	0**	* *	88.92	43	3245	-0.70	93.5	746	95.16	1.03	-21	-0.2	-9.99	-0.6	-5.7	-999	-9.9	0
0312-2								88.92	44	3322	-1.10	93.5	738	95.16	1.03	-20	2.2	-9.99	-0.6	-13.7	-999	-9.9	0
-3								88.92	44	3243	-1.00	93.3	754	95.16	1.02	-20	-0.3	-9.99	-0.8	2.5	-999	-9.9	0
-4								88.91	50	3192	-1.20	93.5	728	95.15	1.02	-14	-1.8	-9.99	-0.5	-23.4	-999	-9.9	0
022002-1	-7.5	33000	0.798	1111	***	0**	* *	86.29	49	3589	0.80	94.5	747	89.65	1.13	-16	0.7	-9.99	-0.6	2.9	-999	-9.9	0
1656-2								86.29	49	3638	0.50	94.6	732	89.65	1.13	-16	2.0	-9.99	-0.5	-12.1	-999	-9.9	0
-3								86.30	48	3565	0.30	94.5	750	89.66	1.15	-17	-0.1	-9.99	-0.6	5.5	-999	-9.9	0
-4								86.30	52	3514	0.40	94.6	727	89.66	1.15	-13	-1.5	-9.99	-0.5	-17.5	-999	-9.9	0
022102-1	-17.3	35000	0.795	1111	***	0**	* *	87.06	47	3457	0.10	93.7	737	92.03	1.00	-17	0.1	-9.99	-0.5	-2.4	-999	-9.9	0
0749-2								87.06	47	3525	-0.10	93.6	726	92.03	1.00	-17	2.0	-9.99	-0.6	-13.4	-999	-9.9	0
-3								87.06	45	3450	-0.30	93.5	741	92.03	1.01	-19	-0.2	-9.99	-0.7	1.2	-999	-9.9	0
-4								87.06	50	3386	-0.20	93.6	720	92.03	1.01	-14	-2.0	-9.99	-0.6	-19.8	-999	-9.9	0
022102-1	-30.0	38990	0.802	1111	***	0**	* *	89.66	43	3278	-1.10	93.1	744	96.91	1.02	-20	-0.6	-9.99	-0.5	-2.6	-999	-9.9	1
0906-2								89.66	44	3355	-1.60	93.2	736	96.91	1.02	-20	1.8	-9.99	-0.3	-10.6	-999	-9.9	0
-3								89.66	43	3276	-1.80	93.0	749	96.91	1.02	-20	-0.6	-9.99	-0.6	2.4	-999	-9.9	0
-4								89.66	50	3234	-1.70	93.0	732	96.91	1.02	-13	-1.9	-9.99	-0.6	-14.6	-999	-9.9	0

On Board Maintenance System (O.M.S.)

- Objectivo- Proporcionar um interface Homem/Máquina de modo a simplificar as operações de manutenção
- Permite - Apresentar mensagens de falha em linguagem corrente /Efectuar testes ao sistemas através de uma unidade central localizada no cockpit - MCDU (Multipurpose Control and Display Unit)



Failure Reduction And Removal - The Maintenance Program Objective

- Aircraft Safety And Operating Efficiency
- Reduce The Loss Of Safety And Reliability Over Time
- Reduce Failures On The Aircraft Through Proper Preventive Maintenance
- Economize On Life-Cycle Costs

NÍVEIS DE MANUTENÇÃO - MAINTENANCE LEVELS

Aeronáutica Civil:

- **Linha da Frente**
- **Manutenção intermédia**
- **Manutenção de base ou Regenerativa**

Base Maintenance

Aeronáutica militar:

- **1º Escalão**
- **2º Escalão**
- **3º Escalão**

Line Maintenance

Over ninety percent of the maintenance performed on an aircraft is preventive or servicing in nature.

DEFINITION

Line maintenance is defined as:

1. Removal or installation of landing gear tyres.
2. Repair of pneumatic tubes of landing gear tyres.
3. Servicing of landing gear wheel bearings.
4. Replacement of defective safety wiring or split pins.
5. Replacement of side windows.
6. Replacement of seats.
7. Repairs to upholstery or decorative furnishings inside the cockpit.
8. Replacement of seat belts or harnesses.
9. Replacement or repair of signs and markings.
10. Replacement of bulbs, reflectors, glasses, lenses and lights.
11. Replacement, cleaning, or setting gaps of, spark plugs.
12. Replacement of batteries.
13. Changing oil filters or air filters.
14. Changing or replenishing engine oil or fuel.
15. Lubrication of components.
16. Replenishment of hydraulic fluid.
17. Application of preservative or protective materials.
18. Removal or replacement of glider tow hooks.
19. Carrying out an inspection of a flight control system that has been assembled, adjusted, repaired, modified or replaced.
20. Carrying out a daily inspection on an aircraft.

MANUTENÇÃO DE BASE OU REGENERATIVA

Base Maintenance or Regenerative

AERONAVE - PROTOCOLO DE MANUTENÇÃO - AIRCRAFT - MAINTENANCE PROTOCOL

1.	Recepção Documental	Documental Reception
2.	Ensaios em solo (se necessário)	Ground tests (if needed – Troubleshooting)
3.	Limpeza	Cleaning
4.	Remoção de combustível(se aplicável)	Defuelling (if applicable)
5.	Posicionamento (doca)	On jacks (maintenance dock)
6.	Ganhar Acessos/Interior	Opening/gaining accesses
7.	Inspecção Básica (A, B. C, check)	Basic Inspection (A, B. C, check)
8.	Anomalias	Findings (related with Basic inspection)
9.	Correcção de Anomalias de Cadernetas	Logbooks corrections (aircraft, engine, accessories)
10.	Boletins de Serviço	Service bulletins
11.	Directivas de Aeronavegabilidade	AD
12.	Trabalho Adicional	Additional work (repairs not related with basic inspection)
13.	Trabalho Suplementar	Supplementary work (engine removal, aircraft painting,…)
14.	Fechar acessos/interior	Closing accesses/interior
15.	Off jacks	Off jacks
16.	Reabastecimento (se aplicável)	Fuelling (se aplicável)
17.	Ensaios no solo	Ground tests
18.	Ponto fixo (se necessário)	Run up (if needed)
19.	Voo de Ensaio (se aplicávle)	Flight test (if applicable)
20.	Documentação(Actualização)	RelatóriosDocumentation (update)/reports

MANUTENÇÃO DE BASE OU REGENERATIVA

Base Maintenance or Regenerative

MOTORES - PROTOCOLO DE MANUTENÇÃO - ENGINES - MAINTENANCE PROTOCOL

1.	Recepção Documental	Documental Reception
2.	Ensaio em banco (se necessário)	Test Run (if needed – troubleshooting)
3.	Desmontagem Total/Parcial	Partial/Total Disassembly
4.	Limpeza de Componentes	Components Cleaning
5.	Inspecção [B´sica]	Inspecção [Basic]
6.	Correcção Anomalias/Reparações	Findings/Repairs
7.	Boletins de Serviço	Service bulletins
8.	Directivas de Aeronavegabilidade	AD
9.	Remontagem	Re-assembly
10.	Ensaio em Banco	Test Run
11.	Inspecção Final	Final Inspection
12.	Contentorização (se aplicável)	In-Container
13.	Documentação (actualização)/Relatórios	Documentation (update)/reports

MANUTENÇÃO DE BASE OU REGENERATIVA
Base Maintenance or Regenerative

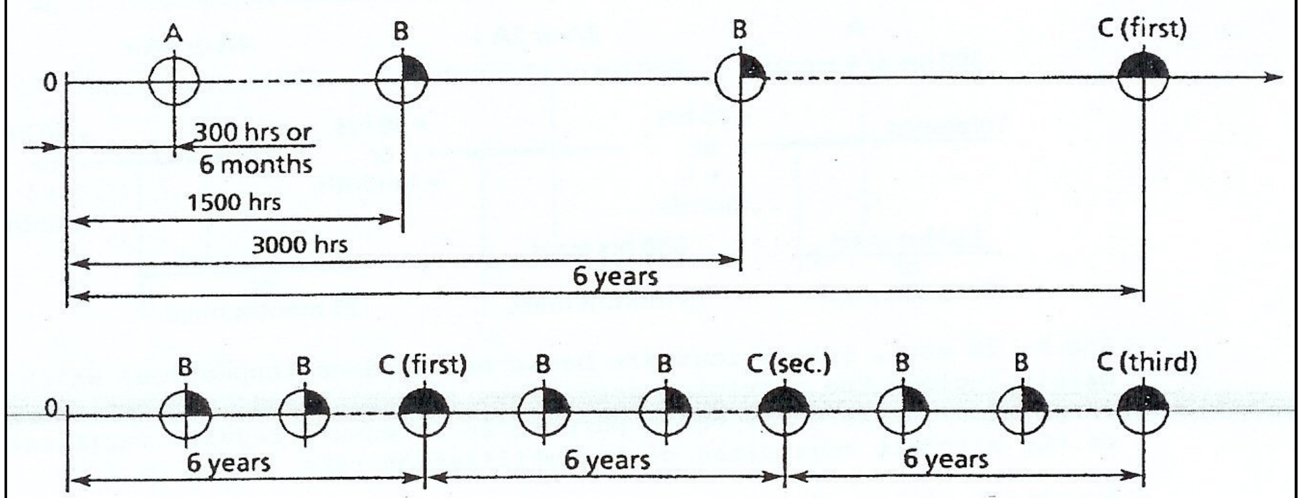
COMPONENTES - PROTOCOLO DE MANUTENÇÃO - COMPONENTS - MAINTENANCE PROTOCOL

1.	Recepção Documental	Documental Reception
2.	Ensaio em banco (se necessário)	Test Run (if needed – troubleshooting)
3.	Desmontagem Total/Parcial	Partial/Total Disassembly
4.	Limpeza de Componentes	Components Cleaning
5.	Inspecção [Básica]	Inspecção [Basic]
6.	Correcção Anomalias/Reparações	Findings/Repairs
7.	Boletins de Serviço	Service bulletins
8.	Directivas de Aeronavegabilidade	AD
9.	Remontagem	Re-assembly
10.	Ensaio em Banco	Test Bench Run
11.	Inspecção Final	Final Inspection
12.	Documentação (actualização)/Relatórios	Documentation (update)/reports

A seguir dá-se como exemplo programas de manutenção de 2 tipos de aeronaves, uma pertencente a uma família de jactos (transporte regional).

The maintenance cycle is based on three types of inspection:
- A inspection,
- B inspection,
- C inspection.

Maintenance cycle :

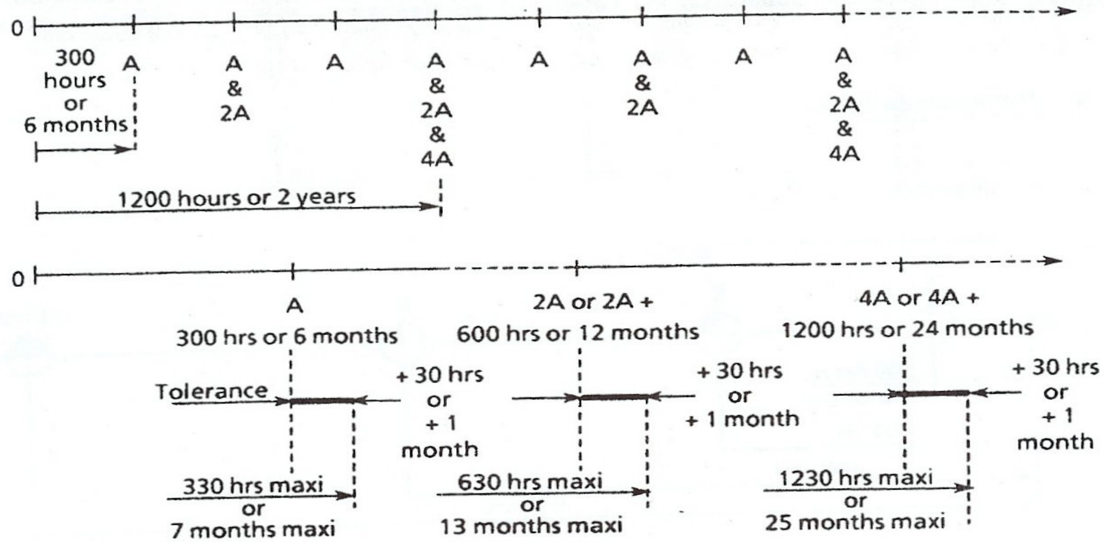


Ciclo global de manutenção (A/B/C)– família jacto executivo

Ciclo de manutenção A

A inspection

– The A inspection must be carried out at 300 flying hours or 6 months, whichever limit is reached first.



– The A, 2A etc., inspections are basic maintenance inspections which mainly include the servicing operations (greasing and lubrication, inspection/check) whose basic purpose is to ensure regular verification of the aircraft regardless of its utilization rate.

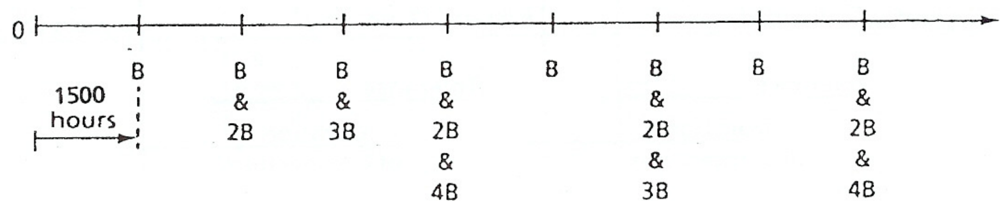
– A certain number of operations are carried out at multiples of the A inspection (identified as 2A, 4A, etc.). They are complementary to the A inspection but are to be carried out only at the times specified for a multiple inspection. The 2A operations are therefore to be scheduled every two A inspections, the 4As once every four A inspections, etc.

Example: the fourth A inspection (1200 hours or 2 years) will include the A inspection operations, plus the 2A inspection operations, plus the 4A inspection operations.

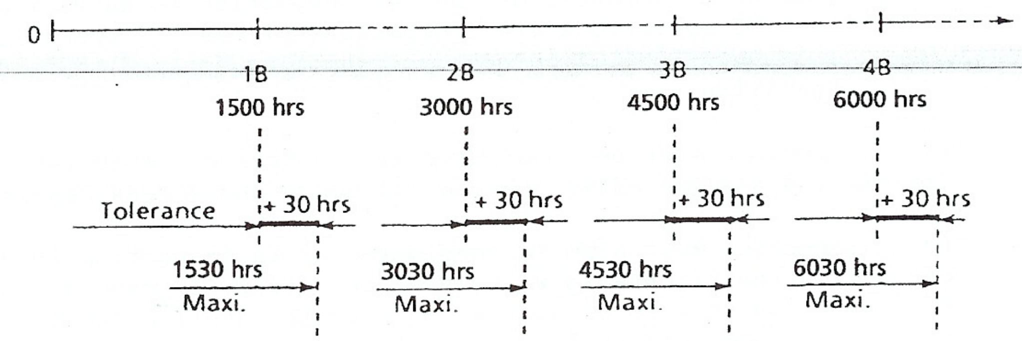
Ciclo de manutenção B

B inspection

- The periodicity of the B inspection is 1500 flying hours.



NOTE (2): The due times for the B inspections are 1500 flying hours and multiples.
The tolerance of 30 flying hours beyond the due time for the B inspection is authorized.



- The purpose of the B inspection is to ensure operational and/or functional capacities of systems whose condition is mainly related to flying hours.

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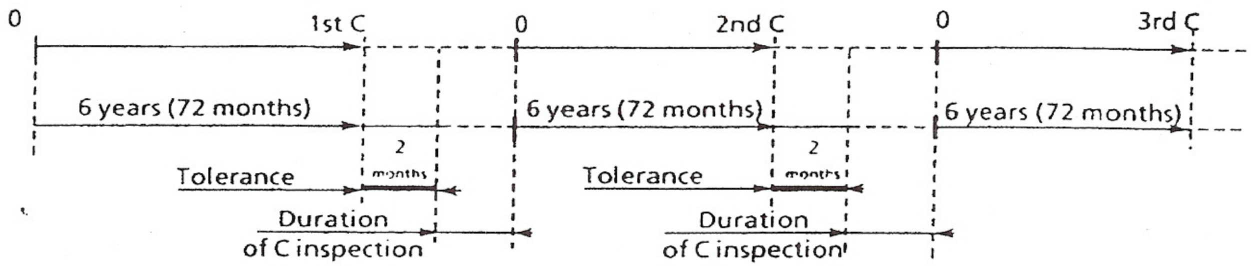
Ciclo de manutenção C

C inspection

- The periodicity of the C inspection is 6 years.



NOTE (3): The manufacturer authorizes a maximum tolerance of + 2 months beyond the C inspection due time.
The duration of the C inspection is not taken into account when determining the interval between two C inspections.

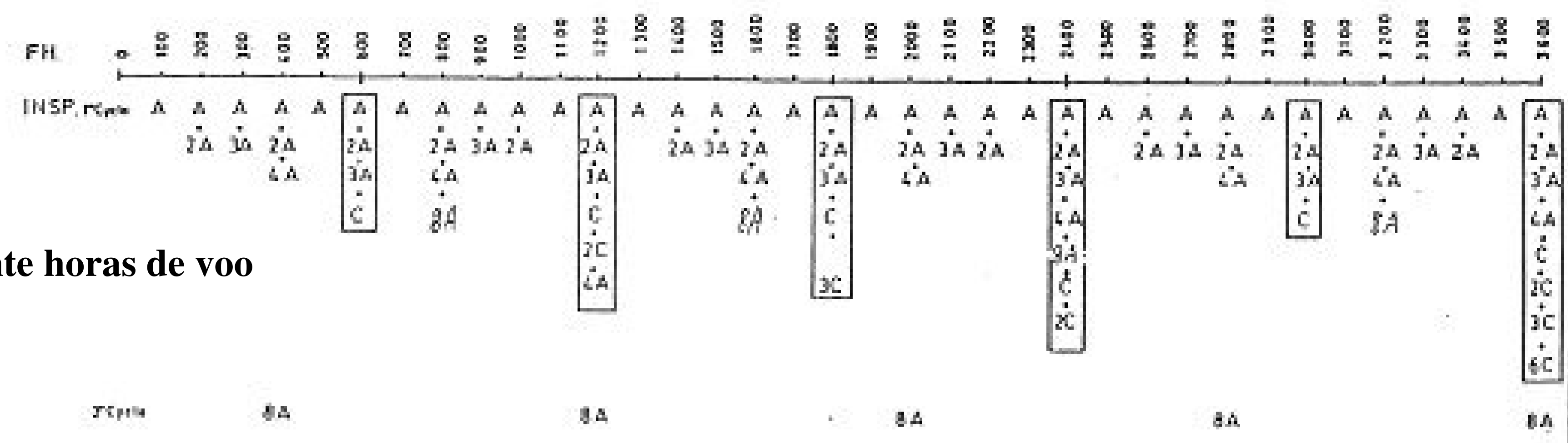
NOTE (4): Cumulate tolerances on the "C" inspection is authorized. As 5-20-00 operations are independant of the "C" operation, tolerances on "C" inspection cannot be applied to 5-20-00 operations.

- The C inspection must be considered as a detailed inspection of the airframe and systems after opening all doors and access panels.

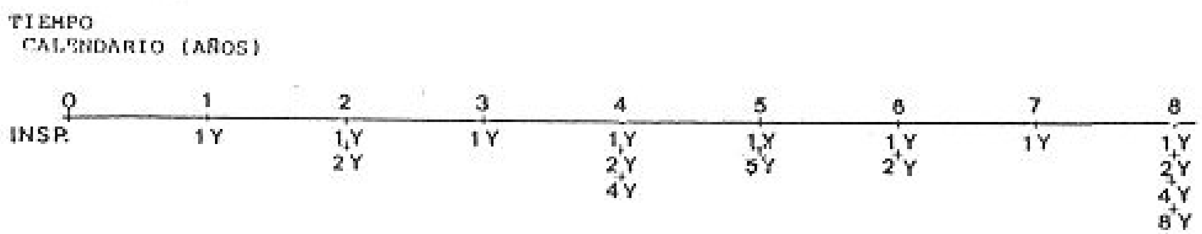
- The C inspection must also be considered as an inspection which, considering the extended down time of the aircraft, should allow reconditioning work to be done as well as the application of Service Bulletins recommended by the manufacturer which are not already applied.

- The C inspection must be supplemented by all operations of the A inspections and multiples of A with flying hours and calendar time limits (A, A+, 2A, 2A+, 4A, 4A+, etc.).

Componente horas de voo



Componente calendário



Ciclo de manutenção global -Aeronave tipo regional

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Manutenção de órgãos/componentes, potenciais e limites de vida

DESCRIPTION OF MAINTENANCE PROCEDURES	MAINT. CONCEPT	INSPECTIONS TYPE / PERIOD.	INSPECTIONS DOC	TBO
LANDING GEAR				
Main gear and doors				
LH leg	HT	R/20000 ldgs	32.15.10	
- Dimensional check and check for corrosion		IC/6 years (1)	474.0	
RH leg	HT	R/20000 ldgs	32.15.10	
- Dimensional check and check for corrosion		IC/6 years (1)	474.0	
LH barrel assembly	HT		32.15.11	6000 ldgs or 12 yrs (2)
RH barrel assembly	HT		32.15.11	6000 ldgs or 12 yrs (2)
LH shock absorber	HT		32.15.12	6000 ldgs or 12 yrs (2)
- LH shock absorber end fitting				

DESCRIPTION OF MAINTENANCE PROCEDURES	MAINT. CONCEPT	INSPECTIONS TYPE / PERIOD.	INSPECTIONS DOC	TBO
RH shock absorber	HT		32.15.12	6000 ldgs or 12 yrs (2)
- RH shock absorbr end fitting				
LH strut actuator	O/C		32.15.14	
- LH dash-pot fitting	HT			
RH strut actuator	O/C		32.15.14	
- RH dash-pot fitting	HT			
NOTE: (1) Tolerance: + 2 months (2) Tolerance: + 5 months				
Nose gear and doors				
Nose gear leg	HT	R/20000 ldgs	32.25.10	
- Dimensional check and check for corrosion		IC/6 years (2)	474.0	
Barrel assembly	HT		32.25.11	6000 ldgs or 12 yrs (1)
Shock absorber	HT		32.25.12	6000 ldgs or 12 yrs (1)

Conceitos de manutenção aplicável a trem de aterragem

Índice de Remoções Prematuras:

Calculado mensalmente para cada componente com média móvel de 3 meses

$$IRP = \frac{RP}{Q_{AC} \times HV} \times 1000$$

Tempo médio entre remoções:

Calculado mensalmente para cada componente com média móvel de 3 e 12 meses

$$MTBF = \frac{QA_{AC} \times HV}{RJ} \qquad MTBUR = \frac{QA_{AC} \times HV}{RP}$$

MTBF - Mean Time Between Failures
MTBUR - Mean Time Between Unschedule Removals

RP - Número de remoções prematuras do componente / equipamento no período considerado.
RJ - Número de remoções prematuras **justificadas** do componente / equipamento no período considerado.
Q_{AC} - Número de unidades por avião.
HV - Horas voadas, no período considerado, pelos aviões, em que a unidade é aplicada.

Mensalmente é emitido um mapa, ordenado por frota, com os componentes cujo $(IRP)_{3M}$ excedeu o IA (índice de Alerta).

O IA é um valor fixo, podendo ser alterado sempre que tal se justifique, por aplicação do Programa de Controlo de Fiabilidade.

O cálculo dos valores limite, efectua-se com base nas equações:

$$LIC = M - 1.96\sigma \qquad LSC = M + 1.96\sigma$$

M - Valor médio do índice de RPs por 1000H.
σ - Desvio padrão.

A excedência de IA motiva uma análise dos mapas por cada um dos gestores de frota a fim de seleccionar um número discreto de componentes, que pela experiência ou tipo de operação, justifica um estudo detalhado no PCF, numa tentativa de repôr o nível de fiabilidade esperado.

O input de unidades a analisar poderá no entanto ser dado por outras fontes dentro dos dados que são possíveis recolher, tais como:

- TSI [Time since installation] por SN
- Atrasos
- Queixas de voo
- Documentos diversos tais como, SBs, SILs, OITs, TFUs
- Informações dos especialistas
- Inputs e dados de outros operadores

Caso se revele impossível repôr os níveis de fiabilidade, torna-se necessário efectuar ajustes no IA.

CASOS PRÁTICOS

RTM

ANALISE FIABILIDADE

FIM DO MÓDULO I

MÓDULO II

2. Corrosão e Fadiga

Introduction

Corrosion, as well as fatigue, is a concern with aircraft structures. Over time, corrosion can degrade the strength of the structure to the point where in-service failure will occur. The design of aircraft and repairs must therefore address the threat of corrosion - this is achieved through careful selection of materials, chemical treatments, paints, primers and the frequent application of corrosion preventive compounds.

- Fatigue and corrosion constitute the two chief threats to structural integrity
- Both must be managed throughout the life of the aircraft – from design to retirement

Pictured at left is the DeHavilland Comet prototype aircraft of 1949. The aircraft was revolutionary in nature taking full advantage of the high altitudes afforded to it by its jet engines. It was designed in an age where knowledge and understanding of fatigue was in its infancy - two crashes attributed to fatigue eliminated this aircraft from the race for commercial success.

Fatigue

Definition: The degradation of strength and stiffness of a structure as a result of the repeated application of cyclic loads during in-service operations

Fatigue

Fatigue Practical - Paperclips:

1. Bend through +/- 90 deg until broken
2. Bend through +/-45 deg until broken
3. Bend through +/- 30 deg until broken
4. Bend through +/-15 deg until broken
5. Life estimation through physical examination

(Note: we will assume that angular displacement is proportional to peak applied loads)

Fatigue

What Simple Conclusions Can We Draw?

1. The higher the peak load, the shorter the life
2. Damage accumulates over time
3. Failure is unpredictable and rapid
4. Fatigue test data has a great deal of scatter
5. Residual fatigue life cannot be determined by physical examination

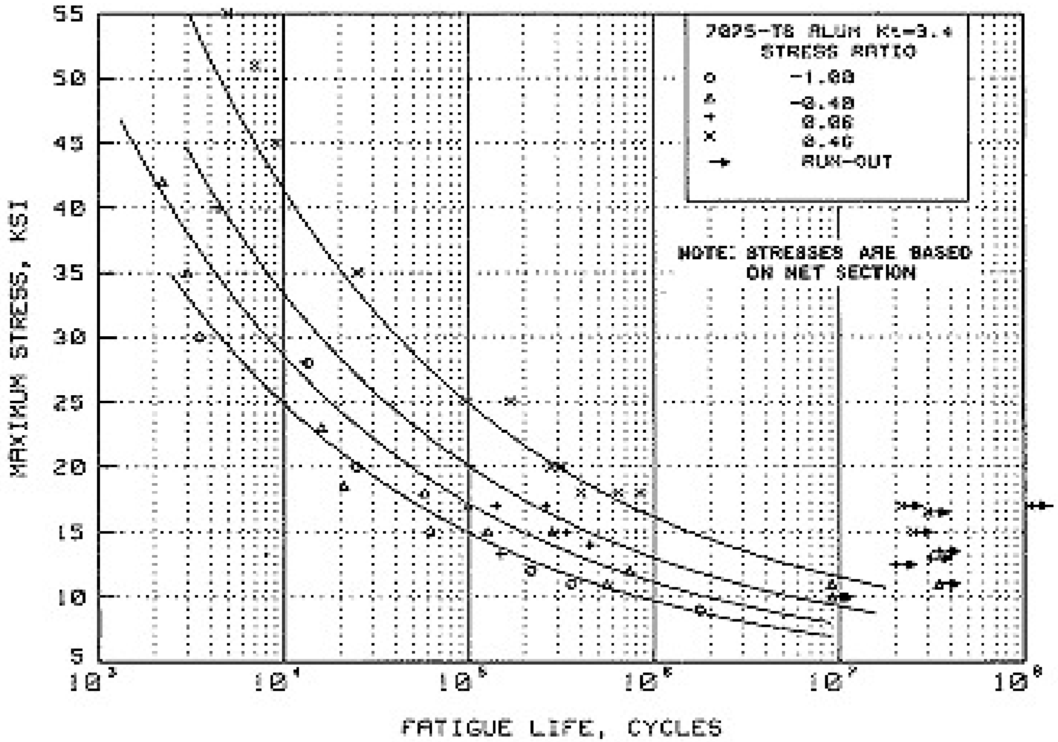
Fatigue

Other less obvious observations are:

- Life is related to the stress ratio (maximum and minimum stresses)
- Tensile stresses must exist for fatigue to occur
- Stress concentrations have a very significant effect on life (they increase local stresses)
- Static strength is not impacted until very late in life
- Every material has its own distinct fatigue qualities

Fatigue (SN Curve)

Fatigue



Note: Stress Ratio (R) is the minimum stress divided by the maximum stress.

Peak stress versus life (cycles) for various stress ratios for 7075-T6 material

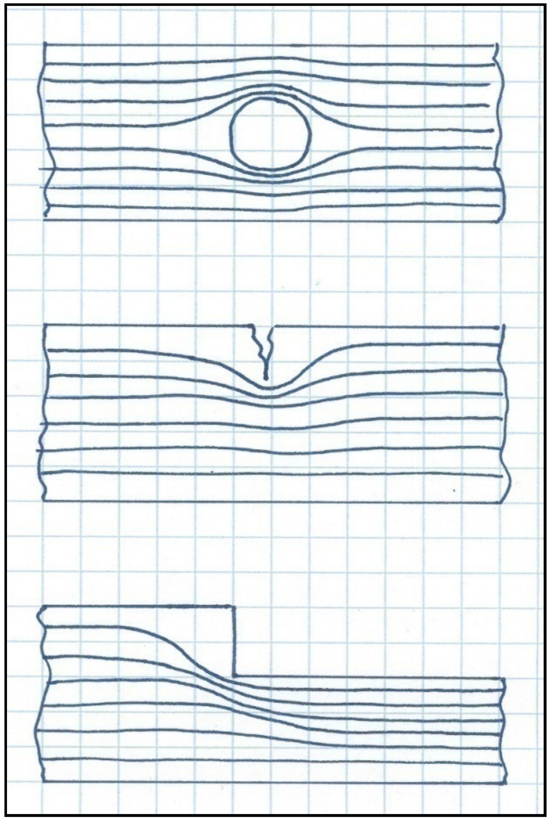
Fatigue

(Stress Concentrations)

Stress concentrations occur at:

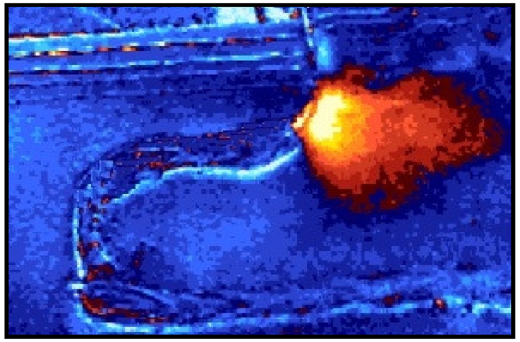
- Holes
- Abrupt changes in cross-section
- Sharp notches
- Material flaws
- Corrosion pits

Fatigue (Stress Concentrations)



- Stress concentrations in tensioned structures can be visualized by considering looking down on a river. The top sketch shows a large boulder in midstream (a hole in a plate), the middle sketch shows a rock outcropping from the bank (a notch), and the lower shows the foundation of a building jutting out into the stream (a step).
- The water must flow around these obstructions and in so doing, the local water stream must speed up
- The closer the water stream lines are to one another, the faster the flow (and the higher the stress concentration factor)

Fatigue (Stress Concentrations)



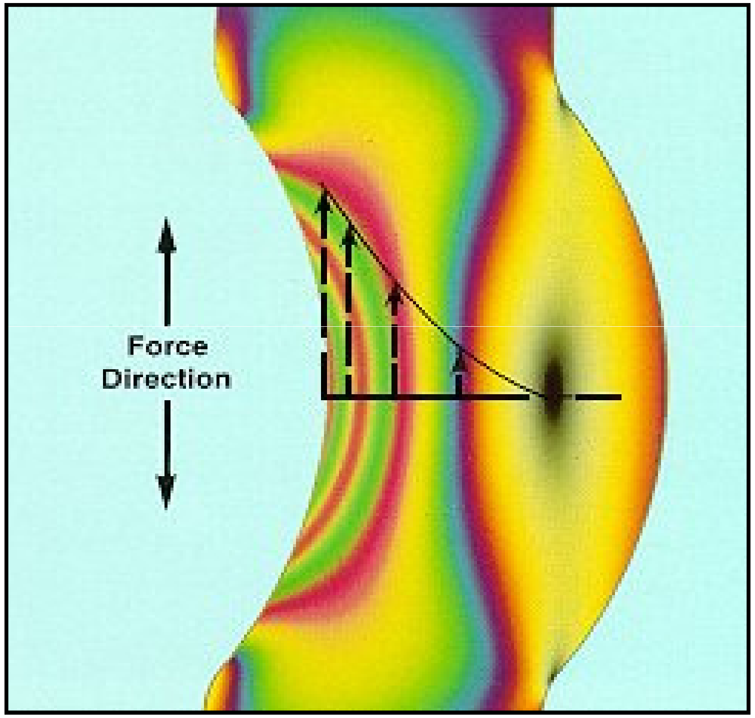
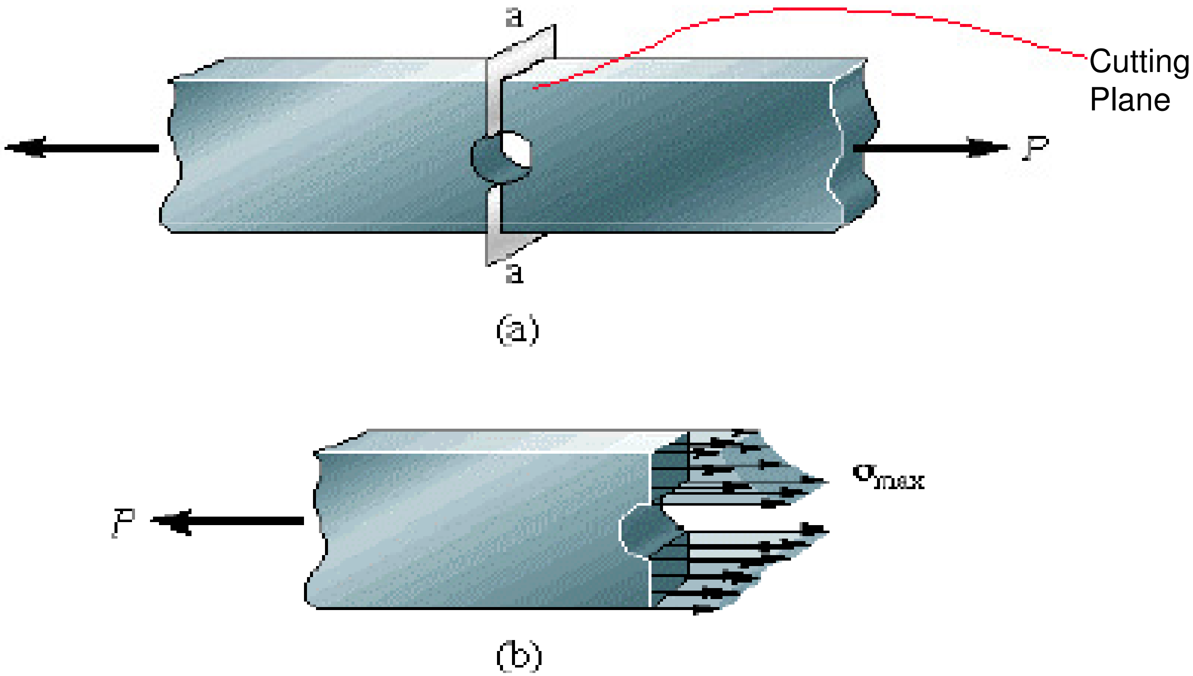


Photo-elastic methods can be used to visually observe strains (and hence stress concentrations). Components are coated in a thin photo-elastic film, loaded up and viewed under polarized light.

Fatigue (Stress Concentrations)

- The stresses at the edge of the hole are three time greater than the stresses remote from the hole. A K_T of 3.0 is said to exist.
- Aircraft are put together with thousands of fasteners each of which requires a hole
- Fatigue cracking often originates at fastener holes



Fatigue (Crack Growth)

- Cracks typically originate at points of highest stress - usually from holes
- Growth has three phases: initiation, crack growth and failure
- At least 2/3 of the life is spent in the initiation phase
- At a certain crack length (the critical crack length a_{crit}), the part will no longer be capable of carrying limit load (the single biggest load anticipated in the life of the aircraft)
- If this limit load is encountered, the crack will rapidly grow and the component will fail

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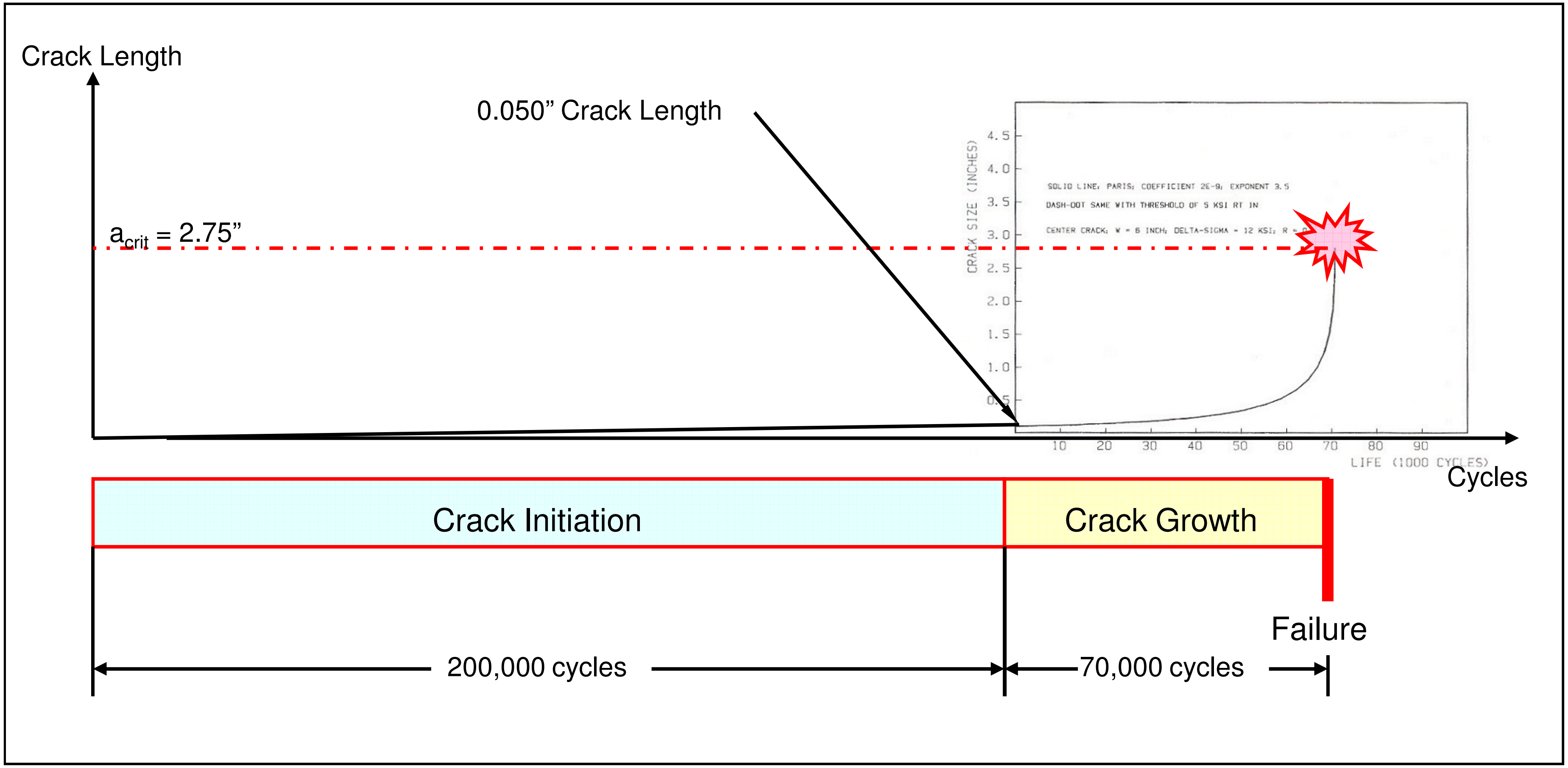
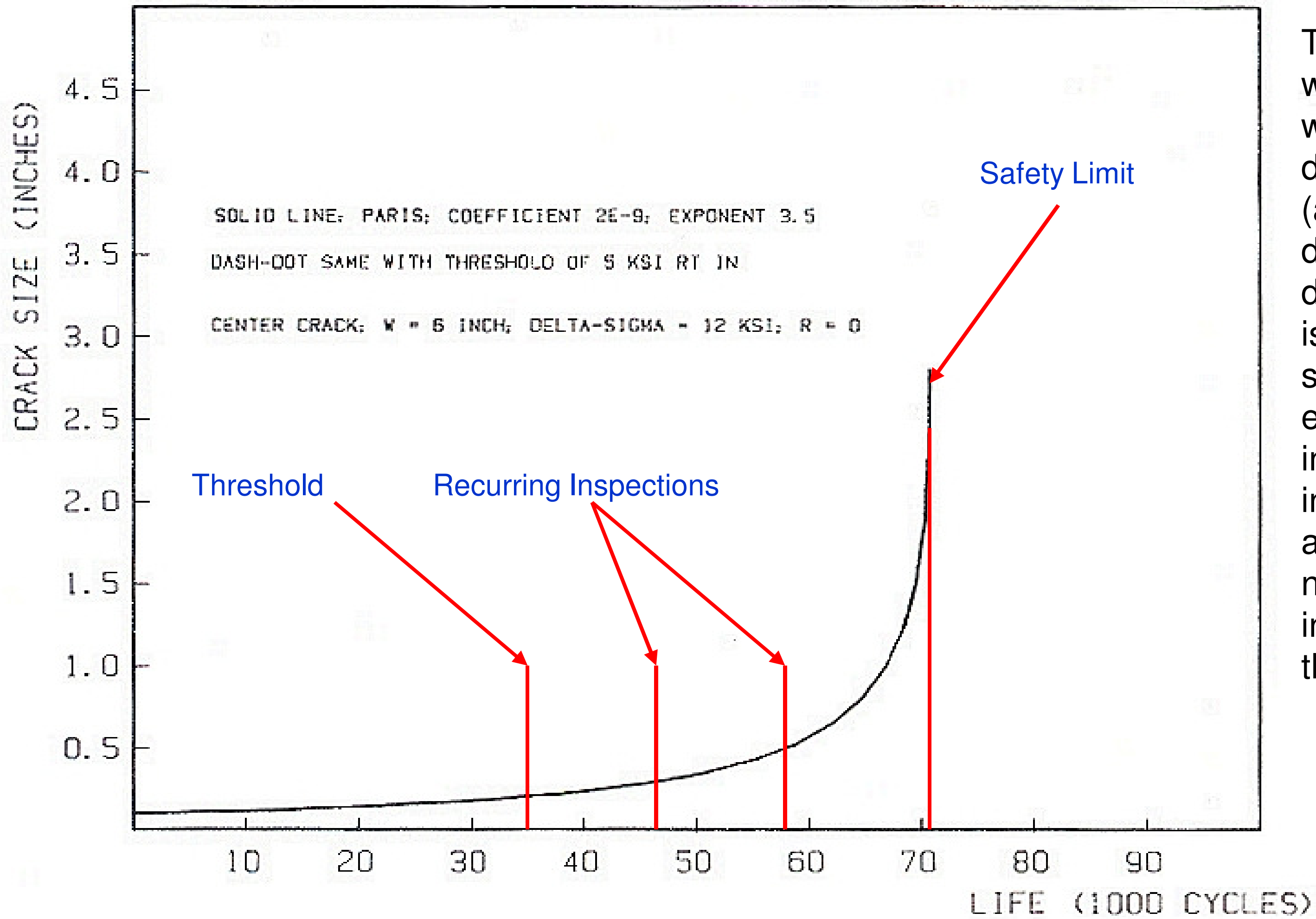
Fatigue (Crack Growth)



- The crack growth phase is the domain of damage tolerance analysis
  - Likely cracking locations are determined
  - Initial flaw sizes of 0.050" on a brand new aircraft are assumed
  - A Stress spectrum is developed for the location based on aircraft operational usage
  - Based on the material properties, the crack is analytically grown to its critical length
  - Inspection thresholds and frequencies are determined based on crack growth characteristics and inspection methods

Fatigue - Crack Growth



The threshold inspection will occur at the time at which the minimum detectable crack length (a_{NDI}) is reached. a_{NDI} is determined by the non-destructive test method that is employed (eddy current surface scan for the example). Two additional inspections will be schedule in between the threshold and the safety limit. Should no damage be found, inspections will continue at the recurring frequency.

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Fatigue - Crack Growth

NDI Technique	Maximum Undetectable Flaw Size - "a_{NDI}" [inch]
Automated Eddy Current: Bolt Hole	0.07
Eddy Current: Bolt Hole	0.12
Eddy Current Surface Scan	0.20 [1]
Low Frequency Eddy Current	0.50 [1]
Ultrasonic Surface Scan	0.20 [1]
X-Ray	1.00 [1]
Directed Visual [2]	2.00 [1]

1 - Location Dependent

2 - Use of optical aid; 10x magnifying glass or borescope

Fatigue - Management

Fatigue can never be eliminated, but it can be effectively managed by:

- Selecting materials with forgiving fatigue qualities
- Utilizing good design practice (edge distance and margin, fastener pitch, surface finish, etc)
- Tight fastener fits
- Surface and hole cold working

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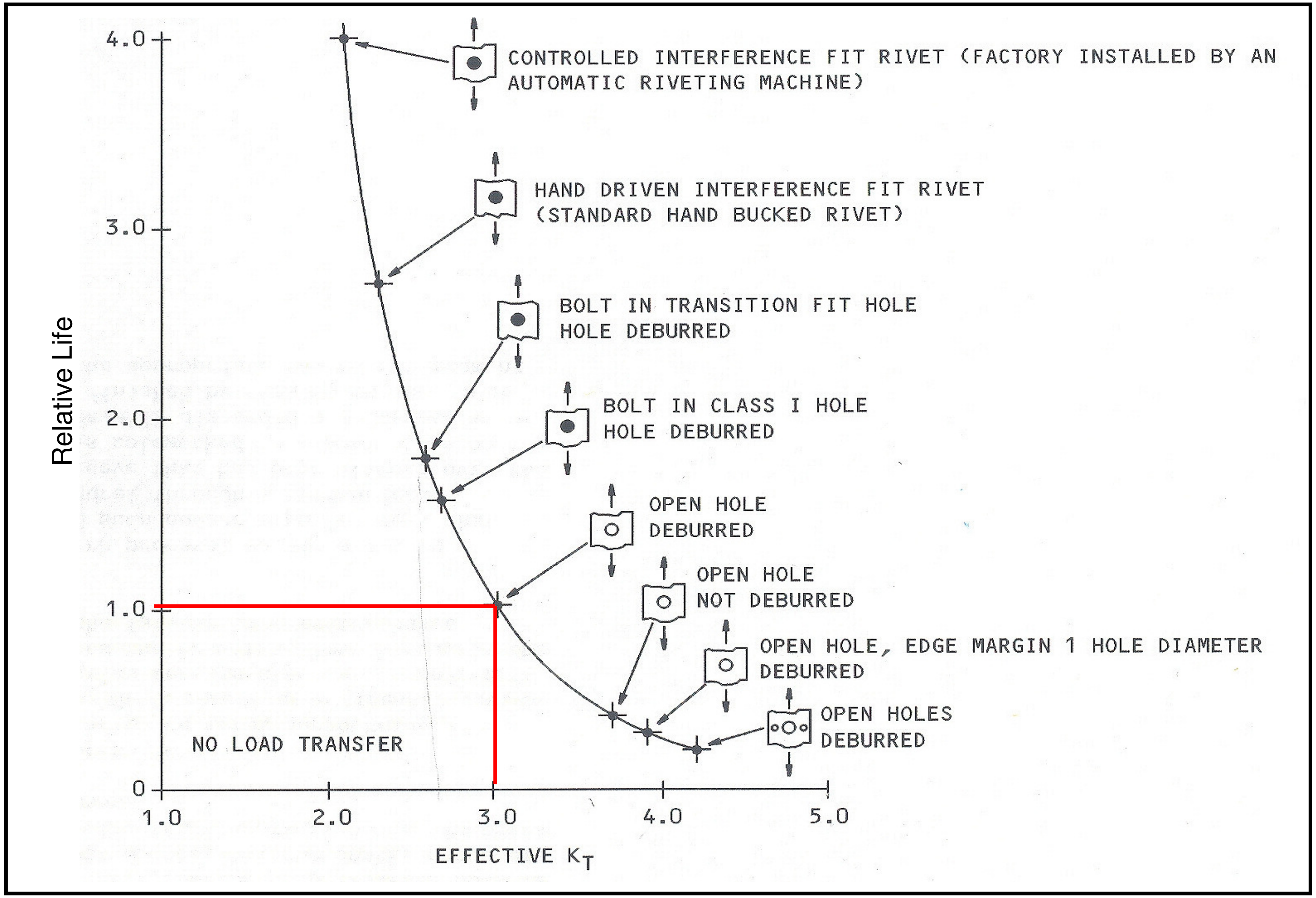
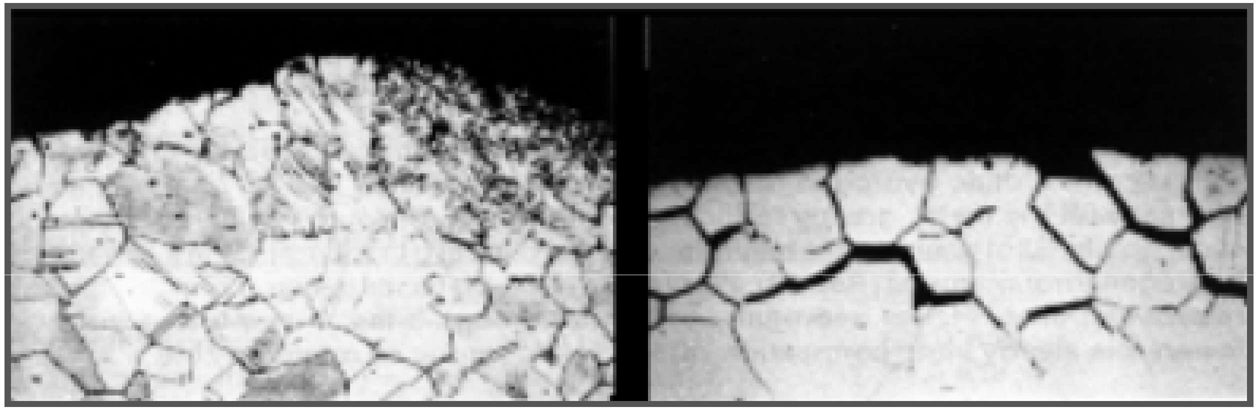
Fatigue - Management



The plot to the left shows the relative fatigue qualities of holes and fasteners with different fits - all are referenced to an open deburred hole. The higher the interference, the better the fatigue qualities.

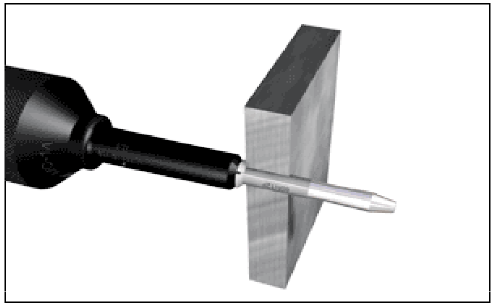
Fatigue - Management

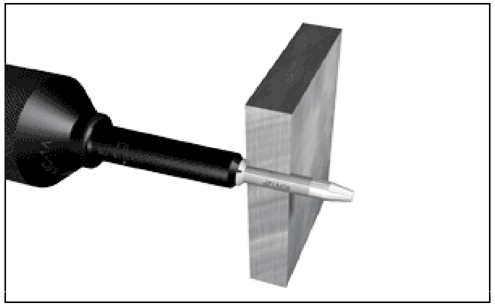


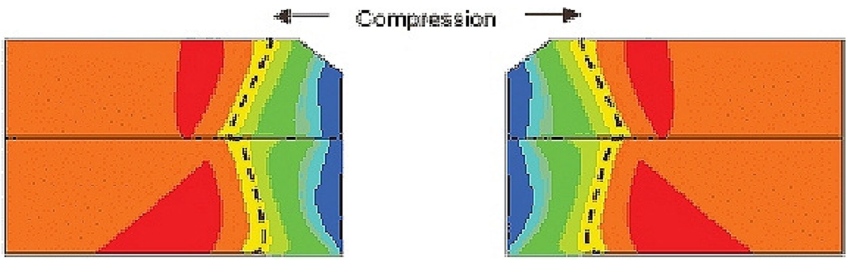
Peened Un-peened

Shot peening is often used to improve the fatigue and corrosion qualities of parts. The process involves bombarding the surface with beads or balls - typically glass, ceramic or steel. A compressive residual stress field at the surface (most often the site of crack initiation) is created.

Fatigue - Management







Cold working of holes is achieved by pulling a mandrel through a hole - the mandrel head diameter plus the sleeve thickness is larger than the diameter of the hole itself. As the mandrel is pulled through, the hole plastically expands leaving behind a residual compressive stress field.

Fatigue - Test

New aircraft designs are subject to comprehensive full scale and component fatigue test programs to validate the life of the airframe and constituent elements.