Ur vårt Digitala Arkiv

The Viggen Aircraft Radar, Reliability Achievement

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INTRODUCTION

ERICSSON has developed, produced and delivered airborne radar systems for three generations of aircraft for the Swedish Air Force. The start was in the 1950:s with radar units for the "Lansen" aircraft. During the 1960:s ERICSSON delivered some 500 radar systems for different versions of the "Dragon" aircraft.

Since 1970 ERICSSONs efforts has been directed towards the different versions of the "Viggen". For the attack version of the "Viggen" a multipurpose solid state, monopulse radar, PS-37/A, is used for ground mapping, air-to-ground ranging, obstacle warning and air-to-air intercepting.

A reconnaissance version of the "Viggen" is equipped with a radar system PS-371/A, of the same basic design as the attack version.

For the interceptor version of the "Viggen" ERICSSON has developed an advanced multimode puls doppler radar, PS-46/A, which is now in full series production. The multimode Viggen Interceptor Radar belongs to a new class of radars which are software controlled. Most radar functions are implemented by software in built-in computers.

In 1982 the development of a new radar generation, the radar for the JAS aircraft, began at ERICSSON.

In this paper the achievement of the reliability goals for the different versions of radar systems of the "Viggen" aircraft are discussed.

SYSTEM DESCRIPTION

ATTACK AND RECONNAISSANCE VERSIONS

The radar systems for the attack and reconnaissance versions of the Viggen are of the same basic design.

The Viggen Attack Radar, PS-37/A, is a Monopulse, X-band Radar consisting of antenna and main unit placed at the front of the aircraft. The antenna unit consists of a parabolic antenna with fixed feed. The main unit contains 13 Line Replaceable Units (LRU:s).

PS-37/A contains more than 5000 parts as shown in the table 1 below.

Part category	Part count
Integrated circuits	5
Transistors	516
Diodes	857
Resistors and potentiometers	1970
Capacitors	1237
Transformers	61
Inductors	109
Connectors	226
Relays	173
Fans, motors	4
Microwave components	31
Tubes	14
Miscellaneous	45
Total	5248

INTERCEPTOR VERSION

The radar for the interceptor version of the Viggen aircraft, PS-46/A is designed as a "cartridge" fixed to the forward aircraft bulkhead with four bolts.

This radar consists of ten LRUs supported or housed in a lightweight frame which in itself constitutes an LRU.

The radar is supplied with electric power, cooling air and hydraulic power by the aircraft. Indirect colling is used through wherever feasible. The two-axes antenna is controlled by hydraulic vane motors.

The digital data and signal processors use flatpacks mounted on multilayer card modules resulting in a very compact and light design. The radar is equipped with an air-cooled 50 kW TWT-transmitter. The total weight of the radar system is 198 kg and the power consumption is 6 kVA.

A continous built-in, automatic supervision informs the pilot of equipment status. High maintainability is provided by extensive bult-in test facilities and functional partitioning into the LRUs. The units are easily exchanged using only two sizes of socket wrenches.

No scheduled maintenance, adjustments or alignment are required at the organizational level.

PS-46/A consits of nearly 10000 parts as shown below.

Part category	Part count
Tubes	4
Integrated circuits	3213
Transistors	312
Diodes	569
Opto	7
Resistors and potentiometers	2576
Capacitors	2265
Microwave components	57
Connectors	292
Transformers	51
Inductors	116
Relays	10
Crystals	7
Miscellaneous	130
Total	9609

RELIABILITY GOALS AND REQUIREMENTS

High technical performance and high availability are needed. There is also a demand for a low life cycle cost, LCC.

The first delivery of the radar for the attack version of the Viggen aircraft was in 1970. Specified MTBF in flight operation is 90 hours. With normal operating profile this is equivalent to 40 mean flight hours between failures (MFHBF). The first delivery for the reconnaissance version was in 1975.

The Viggen Interceptor Radar was ordered in 1969 and the first delivery was in 1978. The contract for this radar incorporates requirements on reliability to be demonstrated during in-house design, development and testing and at field operation. Reliability is a contractual design requirement and has been given the same design emphasis as other performances as output power, weight and power consumption.

Specified MTBF for in flight operation is 100 hours, which at normal use is equivalent to 43 mean flight hours between failures (MFHBF).

RELIABILITY PREDICTIONS

To assure achievement of reliability goals and requirements, as part of the reliability programs, current estimates and predictions have been made during design and development for all three versions of the Viggen radars. These predictions were made to different depth to suit the phase of design and development. During proposal comparisons were made with similar units and systems. Later on in the early design phase the Parts Count Method according to MIL-HDBK-217 (ref.1) was used. During the later design phases the Parts Stress Analysis method was used. When using the Part Stress Analysis method failure rates and factors were taken from MIL-HDBK-217, latest edition. When reliability data was missing or incorrect in the handbook failure rates were taken from the in-house data bank consisting of data obtained from field experiences from systems designed and manufactured by ERICSSON (ref.2).

Results from in-house development testing and flight testing at the aircrift manufacturer Saab-Scania have been used to determine the current reliability status.

The results of the reliability predictions for the attack radar PS-37/A, are presented in the table below.

Year	Method	Failure rate data source	Predicted MTBF, flight operation, in hours	Predicted MFHBF
1966	Parts count	MIL-HDBK-217A	100	44
1968	Part stress	MIL-HDBK-217A	96	43
1970	Part stress	MIL-HDBK-217A	130	58

The results of the reliability predictions for the interceptor radar PS-46/A, are presented below.

Year	Method	Failure rate data source	Predicted MTBF flight operation in hours	Predicted MFHBF
1971	Comparison	Op. history	88	38
1972	Parts count	MIL-HDBK-217A	81	35
1973	"-	MIL-HDBK-217A	86	37
1974	Part stress	MIL-HDBK-217A	140	60
1975	"-	MIL-HDBK-217B	151	65
1979	"-	MIL-HDBK-217B	161	69

As shown in table 4, according to the predictions made 1971, 1972 and 1973, MTBF for PS-46/A was not likely to achieve the specified 100 hours.

According to the prediction made 1973, 40 percent of the total failure rate was due to integrated circuits and semiconductors.

Analysis showed that by introducing a higher quality for these part categories it should be possible to increase MTBF with up to 35%. High part quality, i e level B for integrated circuits and JAN TX for semiconductors, together with some other actions, was judged to be sufficient to assure achievement of the reliability goals.

In consultation with the Swedish Defence Material Administration the introduction of a high component quality was decided.

DATA COLLECTION

To be able to estimate reliability achievement and reliability growth during field operation confident field data are needed.

Collection of field data is often a problem for the contractor.

The Swedish Air Force however uses a well established system for collecting, analyzing and recording all failures and other disturbances that occur during field operation.

During the warranty period fault LRUs are sent to ERICSSON for repair accompanied by a failure report. Even failures corrected at organizational level and other disturbances are reported to ERICSSON. Further more ERICSSON has field engineers stationed at major sites to assist the Air Force personnel. These engineers submit ERICSSON Failure Report Centre with failure data, operating times etc.

Each failure is thoroughly analysed concerning cause of failure and corrective actions that have to be taken.

After termination of the warranty period LRUs replaced at organizational level are sent to the Swedish Air Force central workshop for repair. All failures, including the corrective actions taken, disturbances, preventive actions etc are reported to the Air Force failure reporting system (DIDAS).

Failure report summaries are regularly sent to ERICSSON. These summaries show aircraft number, when the failure was indicated (during flight, landing, test etc), LRU serial number, date of failure, operating time of aircraft and LRU, failure description and corrective action.

Once or twice a year meetings are held with representatives from ERICSSON, the Swedish Defence Material Administration and the Central Workshop. At these meetings all failures reported, as well as repair actions taken and results from failure analysis are studied. An evaluation is made as to whether or not the complaint is verifiable and whether the failure can be regarded as being a primary failure.

When imperfections in design or manufacture are suspected, a deeper failure analysis is made at ERICSSON.

FAILURE CLASSIFICATION AND MFHBF ESTIMATIONS

All failures reported from field have been analysed and classified, regarding cause of failure, as relevant or not relevant.

As relevant are classified failures caused by imperfections in the radar equipment, i e failures in design or manufacturing, part failures etc.

Not relevant are secondary failures, failures due to missuse or accidents, failures in or caused by other equipments and failures not verified at organizational or workshop level.

About 25% of all failures reported have not been possible to verify, neither at organizational level nor at the Central Workshop.

To calculate the operating time on ground the reported equipment operating times have been compared with the number of flight hours for the same period of time. The result has been used when transforming predicted and specified MTBF for flight operation to MFHBF, Mean Flight Hours Between Failures.

For the attack version, PS-37/A, the reconnaissance version, PS-371/A and the interceptor version, PS-46/A, of the Viggen radar, MFHBF has been derived by dividing the total number of flight hours per year by the total number of relevant failures.

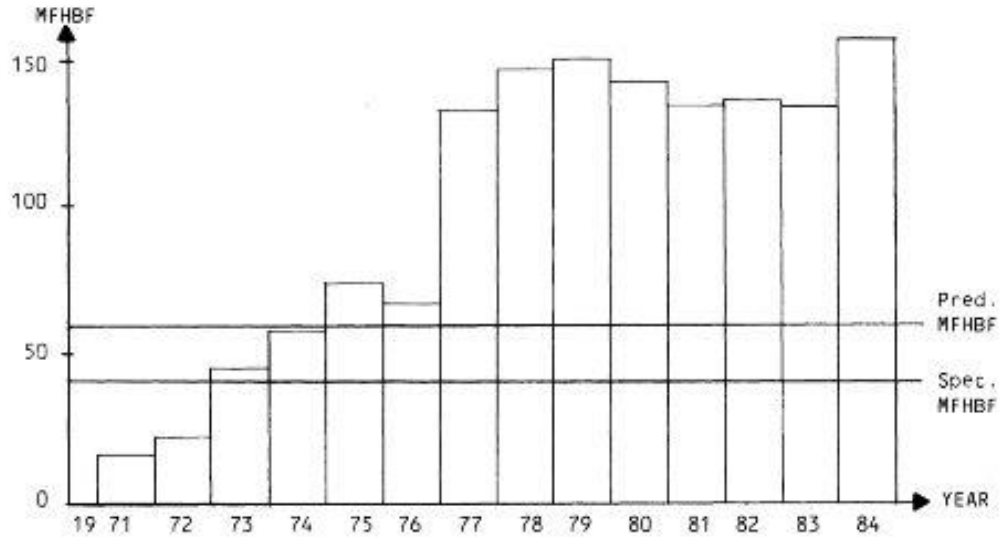
ACHIEVED RELIABILITY

In this section achieved reliability is presented for the different versions of the Viggen radars.

For the attack and reconnaissance versions, PS-37/A and PS-371/A, the result is presented per year and as a function of operating time.

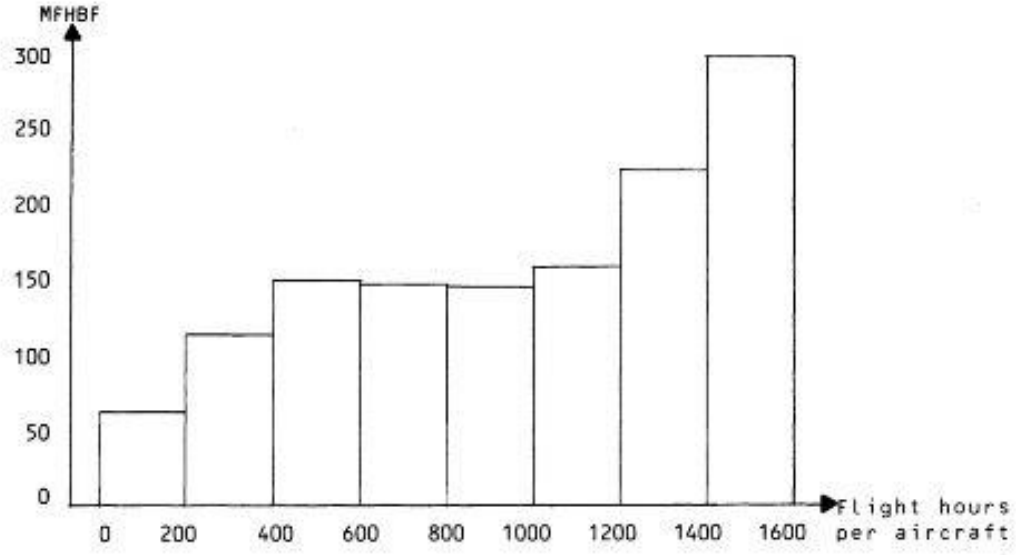
For the interceptor version, PS-46/A, achieved reliability is in this section only given per year.

To facilitate comparisons specified and predicted reliability are inserted.

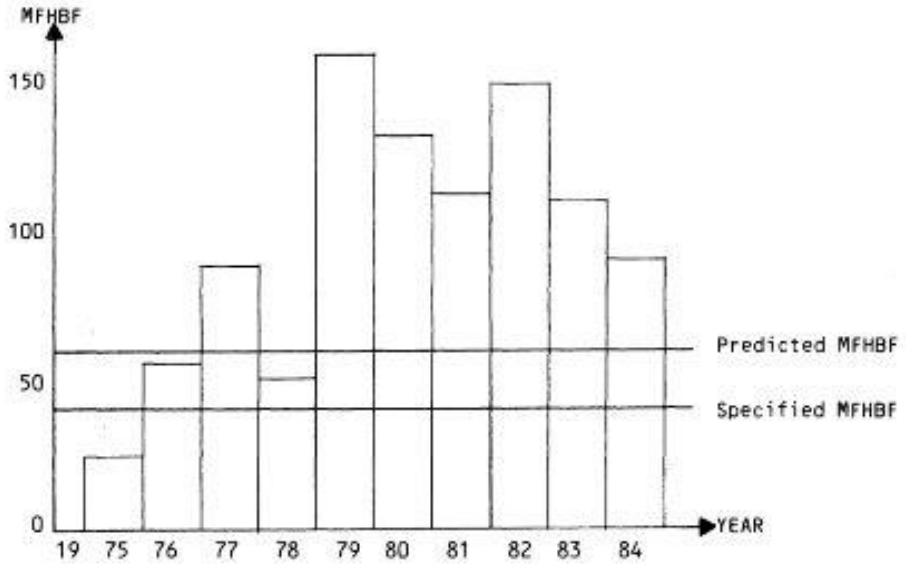


Achieved MFHBF per year for the attack radar (PS-37/A)

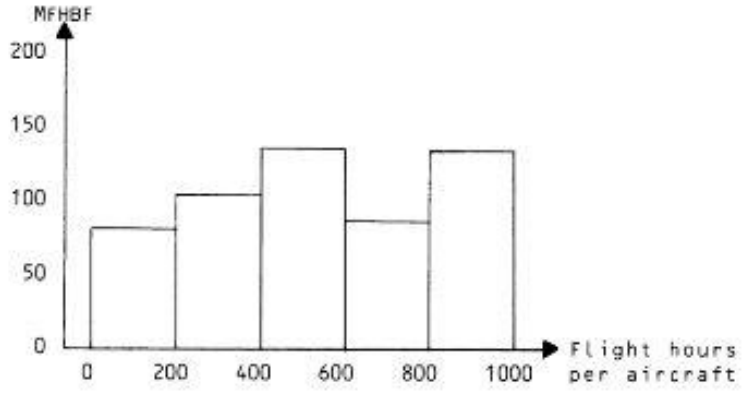
The mean MFHBF for the attack radar as a function of the operating flight hours for the aircrafts is presented below.



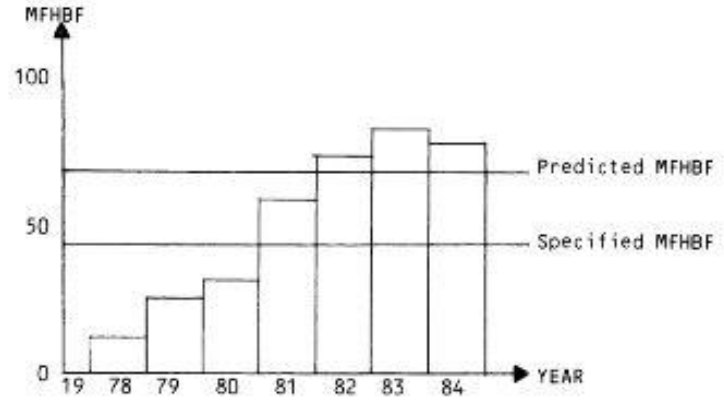
Achieved MFHBF per year for the reconnaissance radar (PS-371/A) is given below.



The mean MFHBF for the reconnaissance radar as a function of the operating flight hours for the aircrafts is presented below.



Achieved MFHBF per year for the interceptor radar (PS-46/A) is given below.



PART FAILURE RATES

In this section observed field failure rates are presented for certain part categories. All part failure rates given concern in flight operation, AIF, as defined in MIL-HDBK-217D, ref 1.

In order not to include infant or early period failures the first 100 hours in flight operation for each equipment are excluded.

The observed mean failure rate per part for a certain part category is given below for the attack and reconnaissance radars.

Part category	Observed mean failure rate in failures per 10^6 hours in flight operation (AIF)
Resistors	0.005
Potentiometers	0.100
Capacitors	0.025
Diodes low power	0.080
Diodes high power	9.200
Diodes microwave	8.000
Transistors	0.400
Thyristors	2.700
Integrated circuits	0.700
Transformer low power	1.700
Transformer high power	100.000
Inductor low power	0.020
Inductor high power	140.000
Relays	1.600
TR-tubes	120.000
Thyratrons	500.000
Magnetrons	150.000
Resolvers	2.200
Waveguide switch	150.000

The same information is presented for the intercepter radar in the table below.

Part category	Observed mean failure rate in failures per 10^6 hours in flight operation (AIF)
Resistors	0.015
Capacitors	0.045
Diodes	0.200
Diodes microwave	1.500
Transistors	0.330
Integrated circuits	0.250
Transformers	0.700
Inductors	0.300
Relays	3.500
TR-tubes	17.000
TWT	625.000
Klystron	175.000
Waveguide switch	100.000
A/D-converters	10.000
Connectors	0.100
Flexible waveguide	100.000

COMPARISON BETWEEN PREDICTED AND ACHIEVED MFHBF FOR LRUs

Predicted and achieved MFHBF for LRUs are presented in the tables below.

LRU	Predicted MFHBF	Achieved MFHBF during	
		1971-1976	1977-1984
Reflector unit	310	220	1600
Turntable unit	1300	1100	1800
Radar rack unit	4000	2900	20000
Filter unit	13000	6700	10000
High voltage unit	1300	490	1300
Transmitter unit	270	300	380
Receiver unit	400	570	1500
Local oscillator unit	570	280	1200
Antenna control unit	670	3300	6700
Test unit	800	4000	16000
Range tracking unit	670	4000	3400
Control logics unit	800	2000	4200
Power unit	800	3300	13000

Predicted and achieved MFHBF for LRUs in the attack radar (PS-37/A)

LRU	Predicted MFHBF	Achieved MFHBF during	
		1978-1982	1983-1984
Turntable unit	860	1460	780
Microwave unit	1000	730	1010
Power unit	4000	--	1760
Exciter	300	120	220
High frequency generator	610	610	590
Illuminator	720	1460	1280
Receiver	620	560	1760
Signal processor	480	730	880
Control unit	1050	360	3530
Reference antenna	70000	7300	--
Radar rack	1100	330	3530
Reflector	24000	3650	--

Predicted and achieved MFHBF for LRUs in the interceptor radar (PS-46/A).

RELIABILITY QUALIFICATION TEST

To demonstrate compliance with specified reliability requirements for the Viggen Interceptor Radar a reliability qualification test has been performed on four production radar systems.

The test was accomplished with the radar systems installed in Viggen aircrafts. During the test period 2550 flight hours were accumulated.

Failure classification was carried out in accordance with MIL-STD-781C (ref 3).

Observed MFHBF, for the four radar systems, was 106 hours. Using 90 percent confidence interval demonstrated MFHBF, was in the intervall 77 to 158 hours, to be compared to 61 hours MFHBF, as specified for the reliability qualification test.

CONCLUSIONS

The reliability progress for the different versions of radar systems for the Viggen aircraft is similar in nature.

Specified reliability was achieved after approximately 5000 flight hours.

For the attack version the best period was achieved after additional 15000 flight hours. The same progress is expected even for the interceptor version.

Observed MFHBF for the best period is 2.5 times higher than predicted value for the attack radar.

These predicted results are supported by the result of the reliability qualification test for the interceptor version.

It is quite obvious that the reliability programs have led to achievement of the reliability requirements.

The reliability predictions made according to different generations of MIL-HDBK-217 have shown rather pessimistic figures. The best period MFHBF observed is better than predicted value with at least a factor of two. A condition for achievement of this high reliability is however that all failures found during flight operation are thoroughly analysed and that all design failures and other systematic failures are corrected.

For the Viggen radars this has been made possible by a close co-operation between ERICSSON and the Swedish Air Force, including reporting of all failures discovered during field operation.

REFERENCES

1 Reliability Prediction of Electronic Equipment, MIL-HDBK-217

2 ERICSSON in-house data bank

3 MIL-STD-781 C. Reliability design qualification and production acceptance tests: exponential distribution.