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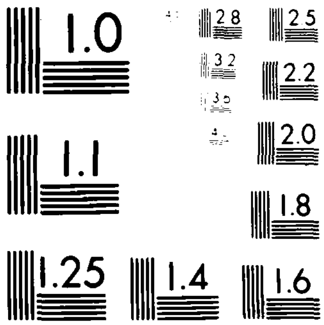

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SURVEY OF P-3C MISSION PROFILES FOR DEVELOPMENT OF THE T56-A-14 DUTY CYCLE

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Mission profiles and maintenance procedures relating to the T56-A-14 turboprop engine were investigated to develop duty cycle information. This information was applied to a derivative engine designated as the 501-M71. A survey of fleet squadron pilots revealed that two profiles account for the majority of flight hours; anti-submarine warfare and pilot training.

The T56 duty cycle was compared with the duty cycle for the 501-M71 derivative. The T56 uses twice as many cycles but less than one quarter of the hot time. This low hot time is attributed

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directly to the present T56 turbine temperature restriction. A new engine or derivative is likely to consume more hot time when operating without this restriction.

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INTRODUCTION

The Naval Air Systems Command (NAVAIR) is currently evaluating the feasibility of replacing the T56-A-14 turboprop engine now in service on several aircraft with a derivative engine, the 501-M71. This engine is commonly referred to as the M71 and reference (a) fully describes its design features.

In reference (b), Detroit Diesel Allison (DDA) has proposed a duty cycle for use in determining M71 component lives. The NAVAIR's concern is to the validity of the proposed duty cycle and has tasked NAVAIRDEVCEN, reference (c), to investigate present P-3 missions relating to T56 engine usage. The duty cycle derived from this survey would be compared with the proposed duty cycle and if significant differences were discovered, then the proposed duty cycle would be changed so that refined life estimates could be calculated.

BACKGROUND

CURRENT ENGINE

The T56-A-14 engine entered production in 1964. It was grown from two earlier models, the −8 and −10W, which entered production in 1959 and 1960 respectively. Horsepower was increased from 3755 in the −8 to 4200 in the −10W and finally to 4591 in the −14. Since 1964, no further performance growth has occurred.

The T56-A-14 is a single-spool, axial flow turboprop engine consisting of a turbine power section connected by the torquemeter housing to a single reduction gear assembly. It has a single propeller shaft that is offset below the turbine power section center line. The feature which most distinguishes this model from the −10W is an air-cooled turbine that permits higher operating temperatures for improved performance and endurance.

DERIVATIVE ENGINE

The M71 engine is essentially a -14 incorporating improvements to each component. Table I provides a list of the modifications which will give the improved performance.

Table I — T56 Engine Modifications to Derive the 501-M71

<u>Gearbox</u>

Incorporate CIP demonstrated improvements
Redesign gearbox bearings
Add forced lubrication to reduction gear drive shaft

<u>Compressor</u>

Replace airfoils to increase efficiency and pressure ratio
Redesign first stage disc

Table I – T56 Engine Modifications to Derive the 501-M71 (Continued)

Combustor

Replace atomizing nozzles with airblast nozzles

Turbine

Increase cooling airflow to reduce metal temperature
Replace first stage materials and coatings

The M71 is expected to achieve the following: 10% lower fuel consumption, 24% greater horsepower, smokeless exhaust, and 25% greater reliability.

APPROACH

A thorough survey of P-3 squadrons was performed (from August 1982 to February 1983) to elicit detailed information concerning mission profiles and standard operating procedures. Topics of discussion included the following: landbased training missions, deployed missions, maintenance checks, ground trims, store loading, NATOPS procedures, engine restrictions, etc.

Each squadron and their respective maintenance shop provided officers and enlisted personnel in support of this survey. They answered questions freely and discussed these topics of interest to any degree required by the interviews. Table II lists each squadron visited by location.

Table II – Patrol Squadrons Visited by Location

NAS Moffett, CA	NAS Brunswich, ME	NAS Jacksonville, FL
VP-31*	VP-8	VP-30*
VP-9	VP-10	VP-5
VP-19	VP-23	VP-16
VP-46	VP-26	VP-24
VP-47	VP-44	VP-45

*Replacement Air Group (RAG) Squadron

Squadrons were selected so that shorebased training as well as operational deployment would be accounted for. The VP-31 and VP-30 squadrons were visited primarily for the purpose of discussing formal pilot training. Here the pilot gets an introduction to the basic flying qualities of the P-3 aircraft. They showed how a pilot transfers from stage-to-stage in the training syllabus. Reference (d) documents the pilots evolution in three stages; they are designated patrol plane third pilot, patrol plane second pilot, and patrol plane commander. There are 52 separate training sessions required to attain the patrol plane commander status. Some missions are flown in the flight simulator, and the majority are performed in the P-3 aircraft.

During the survey, wing records were examined to obtain data relating the frequency of mission to the type of mission discussed. 3M data were also reduced to provide an additional source of mission frequency. The 3M data were sorted by flight purpose code, i.e. mission type.

DISCUSSION OF RESULTS

MISSION PROFILES

Pilots in each squadron were asked to characterize the P-3 missions flown from both their home base and their deployed base. In each case they consistently cited two basic types of mission; pilot training and operational anti-submarine warfare (ASW).

The pilot training flight was estimated to be generally 3-4 hours long with about one hour at moderate altitudes simulating emergencies and corrective procedures. Subsequently, they would come back to the base and practice landings for 1-2 hours. Warning areas directly adjacent to the Naval Air Station (NAS) were commonly chosen for these flights. Pilots estimated the cruise time to be about 15 minutes.

In contrast to pilot training, the ASW flight was characterized by several requirements: submarine detection and localization, surface surveillance, minelaying, torpedo certification and logistics. The minelaying and torpedo profiles were discussed because the high speed/low altitude prompts relatively high power settings that might add to the duty cycle. The surface surveillance profile was characterized by a low speed/low altitude requirement. Logistics flights were described as a high altitude ferry profile to transfer personnel or supplies. These latter four profiles were believed to occur less than 10% of the time.

One other mission that was discussed was the post maintenance check flight. This flight confirms the full functional capability of the T56 after a maintenance action on the engine or gearbox. Table III lists the mission types provided by the surveyed pilots.

Table III – Typical P-3C Mission Types

1. ASW
2. Pilot Training (FAM)
3. Logistics (LOG)
4. Post Maintenance Check Flight (PMCF)
5. Minelaying and Torpedo Certification (MAT)

MISSION FREQUENCY DATA

Two distinct sources of mission frequency data were examined to determine the weighting factors used in calculating the T56 duty cycle. PATWING 10 at NAS Moffett Field provided a complete set of data over several months. These data were segregated by mission type as listed in Table III. Table IV presents these frequency data in their reduced form.

Table IV – Flight Hour Summary by Month

Mission Type	Sept	Oct	Nov	Dec	Average	Percent
ASW	569	486	998	649	675	43
FAM	715	800	585	610	677	43
LOG	95	62	209	132	124	8
PMCF	35	48	46	18	37	2
MAT	89	36	75	33	58	4

These data show an equal weighting for the ASW and FAM missions. Pilots cited a rather sporadic occurrance of the LOG flight, and these data confirm that impression.

A second source of data, 3M, was reduced to provide an overall record of the P-3 community. 3M contains every flight by aircraft type and model. Data was screened by flight purpose code. Four years of data, 1978 through 1981, were reduced and examined in order to find any changes or trends in frequency. No significant trend was discovered. Thus, it was assumed that the present day usage was similar to the 1978 to 1981 years.

Table V presents the 3M frequency data by P-3 model and a weighted average. The weighting factors are shown directly under the respective model in parentheses. They are based on flight hours.

Table V – Mission Percentage Data by P-3 Model

Flight Purpose Code	Mission Type	P-3A (.19)	P-3B (.29)	P-3C (.52)	Weighted Average
1A1	Pilot Training	52.3	30.7	22.4	30.4
1A2	Instruments	26.2	8.4	12.8	14.1
1A8	ASW Training	8.6	15.0	19.8	16.3
1A0	Special Operations	3.1	1.5	1.3	1.7
1L2	Maintenance Check	2.1	2.3	3.5	2.9
1P0	Search and Rescue	0.0	1.2	3.1	2.0
1Q2	Patrol	5.7	31.3	30.9	26.2
1R2	Transport	2.0	9.6	6.2	6.4

These data confirm that pilot training (1A1 and 1A2) and ASW (1A8, 1A0, 1P0, 1Q2) are the most frequent mission type. Pilot training accounts for 44.5% and ASW accounts for 46.2%.

AIRCRAFT CONFIGURATION

Reference (e) specifies the P-3 store loading configuration by code letters A through E. Each letter corresponds to a drag index, with the index increasing from A to E. Surveyed pilots said the typical configuration was A, except in the case of minelaying or torpedo certification. In these two missions, the airplane configuration becomes C or D. Pilots reasoned that the bluff appearance of the large mines place a greater requirement for higher power settings than any other mission. They further commented that minelaying airspeed was attained just under the present engine temperature restrictions.

T56 TEMPERATURE RESTRICTIONS

The current T56 is rated for continuous use at a turbine inlet temperature (T1T) of 1010°C. Because of hot corrosion damage to turbine parts, pilots are presently restricted from using this power setting during climb and cruise. Climb is limited to 950°C and cruise is limited to 925°C. Each pilot surveyed observed the present restrictions except where safety of flight dictated otherwise. Most frequently, pilots related a need to exceed the 950°C with one engine shut down because of an insufficient rate of climb available. Some other cases related are:

(1) Aircraft at heavy gross weight, 135000 pounds on hot day (ambient temperature exceeds 100°F)

(2) Heavy gross weight climb to altitudes exceeding 25,000 feet

(3) Rapid transit to a new datum with one engine shut down

Reference (a) states that the new materials and coatings with improved hot corrosion resistance will eliminate the current T56 temperature operating restrictions. Pilots said they would use the increased power from the M71 for faster climbs and higher cruise altitudes.

FLIGHT PROCEDURES

Procedures of particular interest when considerinq duty cycle calculations are extended periods at high power settings or large throttle excursions of a repetitive nature. Pilots consistently agreed that neither of these procedures are typical of P-3 flight procedures. As previously stated, present restrictions limit the number of occasions when they can select high power settings, yet they did concur that landing practice is performed routinely.

Discussions from each site were in good agreement with respect to typical altitudes and airspeeds There were some differences, because of local base operations, that can and indeed do affect the duty cycle, as will be shown later. Tables VI and VII list the flight conditions and duration of each mission leg. These tables present a typical ASW mission and FAM mission, respectively.

Table VI – ASW Mission Profile

Mission Leg	Duration (min.)	Altitude (feet)	Airspeed (knots)
(1) Warmup	10	0	0
(2) Taxi	5	0	0
(3) Shutdown	–	0	0
(4) Refuel	10	0	0
(5) Startup	1	0	0
(6) Taxi	5	0	0
(7) Takeoff	2	0	0
(8) Climb	25	21,000	200
(9) Cruise	120	21,000	220
(10) Descend	10	2,500	210
(11) Loiter	180	2,500	205
(12) Climb	25	23,000	200
(13) Cruise	120	23,000	230
(14) Descend	15	1,500	210
(15) Land	2	0	0
(16) Refuel	10	0	0
(17) Wash	5	0	0
(18) Shutdown	–	0	0

Note: Loiter is performed using 3 engines

Table VII — Pilot Training Mission Profile

Segment	Duration (min.)	Altitude (feet)	Airspeed (knots)
(1) Warmup	15	0	0
(2) Taxi	2	0	0
(3) Takeoff	2	0	0
(4) Climb	12	10,000	200
(5) Cruise	15	10,000	240
(6) Loiter	90	10,000	210
(7) Cruise	15	10,000	240
(8) Descend	5	800	210
(9) Landing practice	120	800	130
(10) Taxi	2	0	0
(11) Refuel	10	0	0
(12) Wash	5	0	0
(13) Shutdown	–	0	0

Note: Loiter (segment (6)) includes two engine shutdowns

A situation of particular importance to engine usage was found at the NAS Moffett Field. Pilots indicated that NAS Barbars Point was similarly affected in regards to refueling aircraft. Pilots at Moffett and Barbars Point currently refuel after each flight and the allotment of fuel is commonly called a "ramp load"; about 28,000 pounds of fuel. This is sufficient for a FAM sortie but not enough for the ASW mission. Thus, pilots taxi and refuel the aircraft before each ASW flight. While refueling the aircraft, the engines are shutdown and subsequently restarted, which adds two complete start cycles or throttle excursions to the ASW profile. In the same manner, in-flight shutdowns practiced during the FAM profile account for the same additional start cycles. These extra starts, when factored into the duty cycle calculations, will yield a significantly higher usage than expected.

Landing practice was routinely discussed on the FAM mission. Instructor pilots estimated 6 touch and goes for each of two student pilots. They consistently remarked at all three NAS visited that 12 touch and goes per flight was not unusual at all. The 3M data also contained the number of landings per flight. For all three models of the P-3, the weighted average associated with pilot training was 6.8 per flight. This value is low in comparison, yet current base noise restrictions were said to limit the number of landings. For the duty cycle calculations, the 3M value will be used and this explanation for the difference accepted.

MAINTENANCE PROCEDURES

Each powerplant maintenance shop was visited as well as to question and further discuss any significant ground running of the T56 engines. Ground runs are placed in two categories — "low power turns" which generally provide avionics with electrical power and "high power turns" which are done whenever the performance of the engine is in question or some malfunction was cited. Most shop personnel agreed that unscheduled high power turns were more frequent; they estimated about 1-2 per week for a duration of 30 minutes. Although this exceeds the scheduled 28-day interval, it's insignificant when compared to the flight hour accumulation.

DUTY CYCLE ANALYSIS

The duty cycle for the T56/P-3C was calculated in the same manner as described in reference (f). The five missions in Table V were appropriately weighted and summed over a period of 1000 operating hours. The resulting number of missions, cycles, and hot time are shown in Table VIII.

Table VIII – T56 Duty Cycle Summary

Number of Missions	Start Cycles	Idle-MRP-Idle Cycles	Hot Time in Hours
224	640	978	16

It should be noted that a T56 exhibits an extremely low value of hot time, i.e. time above military rated power (MRP). This is because of restrictions discussed previously related to turbine life. Without this restriction, the hot time would increase. For comparison, the estimated duty cycle characteristics are listed in Table IX for the M71.

Table IX – M71 Duty Cycle Summary

Number of Missions	Start Cycles	Idle-MRP-Idle Cycles	Hot Time in Hours
280	280	–	70

The expected usage by the M71 differs radically from that calculated for the T56. There is an observed increase in number of missions due to a shorter average flight length as defined by DDA. Moreover, start cycles are less than half, Idle-MRP-Idle cycles are nonexistant, and hot time is more than four times greater. This hot time is not surprising since an unrestricted T56 could easily accumulate a much higher hot time, even 70 hours. Reference (b) provided no Idle-MRP-Idle cycles in the M71 duty cycle, only a long loiter simulation at part power. Therefore, the observed cyclic operation of the T56 if applied to the M71 may represent a lower fatigue life than previously estimated by DDA.

CONCLUSIONS

Mission profiles and maintenance procedures for the P-3/T56-A-14 weapon system were investigated and found to emphasize two profile types; anti-submarine and pilot training. Both wing records and 3M data indicate that these profiles account for 86-90 per cent of the total engine operating time.

The duty cycle for the present T56-A-14 engine was calculated and compared with that projected for the derivative, 501-M71. T56 usage was shown to require twice as many starts cycles and one quarter the hot time. The low hot time is attributable to present temperature restrictions.

Further, engines using modern technology that fit the P-3 aircraft should be designed to the T56 duty cycle. If the Navy acquires the M71 engine, the DDA proposed duty cycle is considered deficient in its cyclic requirement, and the M71 specification should include the T56 duty cycle as a more realistic design criteria. Any future mission tests should also be compared with the T56 duty cycle to reveal their usage severity.

ACKNOWLEDGEMENTS

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REFERENCES

(a) DDA Briefing, "501-M71 Engine for Navy Application", Number EDR 9608 dated 22 Sept 1978

(b) DDA Briefing, "501-M71 Status and Design Summary", Meeting held at NAVAIR, 14 May 1982

(c) "Operational Environment for Aircraft Engines", AIRTASK 5365360 0012 3W13550000, Amendment H dated 18 Aug 1982

(d) "Personnel Qualification Standard for P-3 Aircrew-Pilots", Report NAVEDTRA 43236-0A dated June 1978

(e) "NATOPS Flight Manual", NAVAIR 01-75PAC-1, dated 15 Feb 1971

(f) Navairdevcen Report No. 77501-30 dated 23 Apr 1979

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