~~TOP SECRET~~ RD-A-6B

HANDLE VIA
BYEMAN
CONTROL SYSTEM

~~(S)~~ NATIONAL RECONNAISSANCE OFFICE
WASHINGTON, D.C.

THE NRO STAFF

29 April 1974

MEMORANDUM FOR COL RAY ANDERSON, SAFSP-7

SUBJECT: HEXAGON Long Life

The attached document on HEXAGON Long Life is forwarded for your information. This version of the topic paper was coordinated with all elements of the NRO Staff and Comptroller. The document may undergo additional modification subsequent to review by the IC Staff and other ISMS participants.

Many thanks to you and your staff for the fine work performed on the document and quick response to my questions. Please accept my apologies for any subsequent queries and work which may occur as a result of your efforts in producing the original document.

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Attachment
BYE-12867-74

BYE-12870/74 1 4

HEXAGON
HANDLE VIA
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PAGE 1 OF 1 PAGES

HEXAGON LONG LIFE

ABSTRACT

1. Since its first flight, the HEXAGON vehicle has demonstrated outstanding growth and a large potential remains for additional increases in mission duration. Active mission life has increased from 31 days for mission 1201 to 102 days for mission 1207. Although some problems have surfaced during the previous missions, the basic design of the HEXAGON vehicle has proved to yield far more active mission life than the originally intended 45 days. To overcome design deficiencies, some design changes have been incorporated during major block changes where appropriate. System reliability has been and continues to be, increased through a process of improved piece-part selection, manufacturing, assembly, and test. These minimal changes have resulted in the capability of the present vehicle configuration to sustain mission durations of approximately 120 days. Additional reliability improvements that are being incorporated for Block III vehicles (SV-13 and subsequent) will permit the option of extending beyond 120-day missions; possibly up to mission durations on the order of 180 days.

INTRODUCTION

2. BACKGROUND

a. Initial HEXAGON planning envisioned five flights each year launched on 60-day centers. As funding became more critical and system success was proven, this schedule was reduced to four flights each year, then three flights each year and, starting with mission 1209, two flights per year. The HEXAGON system was designed for an active life of 45 days; however, Block I flights (missions 1201 through 1206) were planned for 30 days duration and contracts were incentivised accordingly. It was planned to fly 45-day missions starting with 1207. It was assumed by both SAFSP and the Satellite Operations Center (SOC) that four 30-day flights each year would be necessary to satisfy all requirements.

b. In terms of preflight objectives, mission 1201 was highly successful. The primary mission was terminated with the recovery of RV-4 on Day 31, and the vehicle was then flown for 20 additional days (SOLO operation) to gain engineering data. The problems encountered were of the type that could be corrected prior to Satellite Vehicle Two (SV-2) launch or compensation could be achieved using operational techniques. Subsequent to the flight, the 30-day maximum mission life concept was seriously questioned. It was evident that the HEXAGON vehicle was capable of mission operations in excess of 30 days. It was also clear that from a mission satisfaction standpoint, longer flights were desirable in that:

(1) Longer life results in a greater number of accesses for all targets.

(2) Longer life combined with proportionately higher weather thresholds results in a larger percentage of cloud free photography. This factor is extremely important in terms of maintaining high accomplishment levels for long-term standing requirements.

(3) Long-term repetitive coverage of cluster targets and other high priority targets is not feasible without long mission lifetimes.

(4) Longer mission lifetimes provide a higher probability of having a photo-vehicle on orbit when "high interest" situations develop.

c. Discussions between SAFSP-7, [redacted] the CIA west coast field office, the SOC and between SP-7 and the hardware contractors were initiated to define how long the hardware could reasonably be expected to operate and, from a mission effectiveness standpoint, what was the optimum mission length. A logical step function process leading to longer life was initiated. Basically the concept was: (1) Plan each flight's length based upon information obtained from the preceeding flight; (2) Plan, with the SOC, such that extensions could profitably be used if a vehicle performed better than expected; (3) Conduct comprehensive SOLO testing to gain information regarding longer life and hardware problem resolution; and (4) Increase hardware reliability. Flight history to date is summarized below in Figure 1.

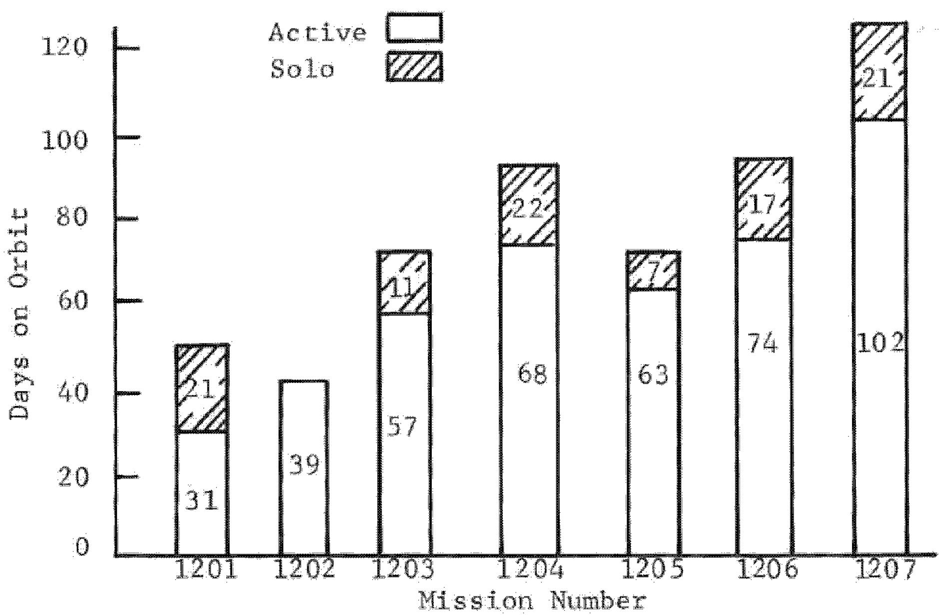

Figure 1

d. Like the HEXAGON vehicle, the operational software at both the SOC and the AFSCF was originally designed for four missions per year, each with an active duration of 30-45 days. As such, some of the algorithms used in the mission planning and operational software do not reflect adequately the current philosophy of two 120 to 180-day film-limited missions per year. These algorithms currently are being reviewed and some of them may be modified and/or replaced to assure maximum film utilization efficiency over the extended mission lifetimes.

3. PARTICIPANTS

a. SAFSP: Responsible for Satellite Vehicle, Recovery Vehicles, Mappimg Camera Module, Vehicle Integration, Launch and On-Orbit Operation. As of 1 July 1973, assumed responsibility for the Pan Camera System hardware.

b. SOC: Responsible for mission requirements and provides on-orbit targeting guidance to SAFSP.

c. CIA: Responsible for Pan Camera System hardware from program approval through 30 June 1973. Provides mission planning and analysis support to the SOC.

d. AFSCF: Responsible for orbital support of the HEXAGON vehicle to include recovery of reentry vehicles.

PROBLEM STATEMENT

4. What is the maximum reasonable life expectancy of the HEXAGON vehicle without major modifications to existing hardware?

SCOPE AND LIMITATIONS

5. The scope of this annex is limited to:

a. Discussion of the growth of the HEXAGON vehicle.

b. Discussion of the long life capability of the HEXAGON vehicle.

c. Discussion of potential vehicle modifications that would improve system performance and their possible implementation dates.

d. A cost analysis is beyond the scope of this annex. However, it should be noted that significant costs would be incurred if contractual guarantees for long life missions were to be secured.

e. Quantifying mission effectiveness based upon longer mission life is beyond the scope of this annex.

ANALYSIS

6. To address the question of longer mission life one must examine the reliability aspects of flying longer, the interplay between consumables and longer flights, and ultimately trade these factors off against increased mission effectiveness gained by having a vehicle on-orbit for a longer period of time.

7. a. General: The HEXAGON system has proven to be extremely reliable. Reliability was designed into the system from a piece-parts, component, system, test and operational standpoint. The basic satellite vehicle has completely redundant systems except for the orbit adjust engine and power system. In addition, there is considerable cross-strapping capability at the module level between the primary and redundant system. (It should be noted that utilizing a redundant system is transparent from a mission standpoint since redundant systems have the same capability as a primary system.) There are a large number of single point failure modes in the pan camera system. The majority of these are associated with the camera electronics. These modes are being eliminated through incorporation of an independent camera system emergency shut-down capability and a redesign of the camera electronics. This reliability improvement will be implemented as a Block III vehicle (SV-13 and subsequent) change. There are, of course, single point failure modes within the film path; however, there is no practical way to design redundancy into the film transport system. Based upon demonstrated reliability through mission 1207, the operational flexibility inherent in the HEXAGON vehicle, and the redundancy built into the system, it is SAFSP's considered opinion that once a vehicle achieves orbit and is operating nominally, the hardware can support long life missions with a high degree of confidence.

b. Time dependent or "wearout" failures.

(1) Reaction Control Thrusters (RCS). The RCS thrusters, which are used to control vehicle attitude, show a gradual degradation that can be related to time on orbit. The failure mode is

graceful in nature, taking place over a period of weeks. Each vehicle flown to date has evidenced some degree of thrust degradation. The failure mode is well known, well understood, and the effect can be minimized through operational means. During missions 1206 and 1207 some 90 days of mission life was achieved on each vehicle operating on a single set of thrusters. The redundant thrusters are identical to the primary thrusters; therefore, one can assume that the vehicle has the capability to fly for 180 days if thrusters are used back-to-back. This, of course, assumes that no other type thruster failure occurs. To mitigate against other potential failure modes Block III vehicles will have a cross-strapping capability between primary and redundant thrusters down to the thruster pair level. In addition, the Block III thrusters are being redesigned to alleviate the catalyst bed degradation problem.

(2) Pyro and lifeboat battery cell failure. The pyro and lifeboat batteries can be expected to fail between 127 and 145 days of orbital life due to cell degradation. The failure mode is catastrophic in nature and occurs with little or no warning. The pyro battery supplies power to the reentry vehicle release circuit; therefore, when the pyro batteries fail,capsule recovery is impossible. The lifeboat system provides a backup recovery and deboost mode and is used when both primary and redundant attitude control systems have failed. The potential pyro and lifeboat battery failure effectively limits present mission life to 120 days. A modification has been approved effective with SV-11 (mission 1211) to replace the present system with rechargeable batteries. Rechargeable batteries have an anticipated life of 12 months.

c. Failures other than wear-out are calculated based upon statistical data. Basic reliability can be increased by more stringent piece-part selection, increased emphasis on quality during manufacturing and by more perceptive testing at all stages of vehicle assembly. All of these steps have been taken; Block III vehicle piece-part selection, manufacture quality control and testing is even more stringent than that required for Block I and II vehicles.

CONSUMABLES

8. a. Propellant. The primary life limiting consumable is propellant. A monopropellant (Hydrazine) is used in both the orbit adjust and reaction control systems. The RCS and OA tanks are cross connected in such a manner that the RCS thrusters can be operated from the OA tank. In general, the thrusters can operate for 50 days from each pair of RCS tanks; when the RCS tank propellant is depleted, the thrusters are then fed from the OA tank. Cross-strapping between the OA tank, RCS tanks, and RCS thrusters is adequate for all contingencies.

(1) Each pair of RCS tanks is loaded with 197 pounds of hydrazine; the OA tank is loaded with 3200 pounds. Propellant is expelled from the tanks to the engines by means of a nitrogen blow down technique. Orbital life and altitude for any mission is determined by the amount of propellant available. By increasing altitude, life can also be increased; however, by increasing available propellant, life can be increased by some delta time without affecting mission altitude.

(2) To provide added capability, SAFSP directed LMSC to determine the feasibility and cost of increasing the OA tank propellant by 800 pounds. There are two repressurization techniques that take advantage of the present OA tank ullage space to increase the propellant load. Both techniques appear feasible; however, it is unlikely that the 4000 pound tank capacity can be provided prior to SV-16. Various mission life/altitude options are summarized below. (A 1980 high drag profile was used.)

PRESENT OA TANK (3200 LBS)

LIFE	ALTITUDE
90	83
120	89
150	94
180	98

STUFFED OA TANK (4000 LBS)

90	82
120	84
150	90
180	94

b. Film. One can assume that additional film capacity is desirable, especially when flying longer missions. There are two obvious methods of effectively making more film available for photographic operations; first, make more efficient use of the present film supply, and secondly, increase the supply. Various efforts which address these two aspects of long life are presently under study and are summarized below.

(1) Elimination of the film rewind constraint. The present system has a film load capacity of 110,000 feet of type 1414 film per side. Of this 110,000 feet some 30,000 feet is unavailable for photographic operations due to interoperation wastage and lack of film rewind during a mission of 1,000 camera operates. The system is designed to rewind a particular amount of exposed film back into the supply area after each camera operate sequence. The exact amount of film rewound is a function of the next operate scan mode. This particular technique reduces interoperate film wastage to a minimum by using previously exposed film during the film path acceleration process. The amount of film rewound is calculated such that the film path reaches the proper constant velocity (Vx/h) at essentially the same time the exposed film clears the platen, thus optimizing film usage and protecting against double exposure. Utilizing a full rewind capability makes a maximum of 17,000 feet of interoperate film available for intelligence operation, per side, for a 1,000 camera operate mission, that is not available when rewind is constrained. Rewind was nominal for missions 1201, 1202 and the first two RVs of 1203. During segments three and four of mission 1203, film fold-over occurred in the RV takeups. The fold-over was traced to problems in building an even film stack on the takeup during the rewind process. Rewind was prohibited for mission 1204 and subsequent vehicles pending successful resolution of the problem. The fix that will permit rewind involves a redesign of the takeup builder roller. The first three modified takeups will be flown on mission 1210.

(2) Provide a Negative Constant Velocity (NCV) capability. As part of the mission optimization process the HEXAGON system initiated a one-rev load cycle on mission 1204. A one-rev load cycle, where camera operates are selected for only the upcoming rev, optimizes the use of weather prediction in target selection. However, it also leads to inefficient rewind. The software looks ahead for a target selection on the following rev to determine

the exact amount of rewind required. Since no subsequent targets are selected on a one-rev load cycle, the software rewinds to take care of a worst case mode. This technique wastes between 5,000 and 6,000 feet of film, per side, per mission. Incorporating a NCV rewind technique would permit the system to move film in a reverse mode once a target and scan mode is selected. The software would determine the optimum amount of negative film movement and, as part of the normal camera operate sequence, position previously exposed film accordingly. This capability is being studied for incorporation in mission 1213. In summary, the capability to be gained by eliminating the rewind constraint is 17,000 feet, per mission. By adding the NCV modification an additional 5,000 feet of available film could be utilized.

(3) Increasing the amount of film loaded on the supply. Film is loaded on the supply based upon a radius criteria. This criteria is being reexamined in light of flight history to date. It appears that an additional 5,000 feet of film could be safely loaded on each supply. This determination will be made prior to makeup of the mission 1209 supply.

(4) Ultra-Ultra thin based film. Eastman Kodak is developing and evaluating a new film base that is 1.3 mils thick as compared to the present 1.5 mil 1414 film used by the HEXAGON system. Samples of this film will be provided to the camera contractor for testing in the near future. If the HEXAGON vehicle can use this film, it would mean an increase of approximately 12,000 feet of film per side.

(5) As part of the normal system improvement program, SAFSP is examining techniques that would improve the film transport system to eliminate or reduce interoperate wastage, provide greater operational flexibility in scan mode selection within operates, and improve film transport reliability. These are long-range improvements and if feasible and cost effective, could be incorporated into the system as a planned block change for vehicle 19.

SUMMARY - INCREASED FILM (TYPE 1414)

	Film Availability Increase	Total on Supply (Spec Value)
1. Eliminate Rewind Constraint	17,000	110,000 *
2. Incorporate NCV Capability	5,000	110,000 *
3. Increase Supply Radius	5,000	115,000
4. Ultra-Ultra thin based film	12,000	122,000

*Average value on supply (based on thickness).

c. Pneumatics. The pneumatics system supplies gas to the film transport system. The present capacity, 32 pounds, is being doubled commencing with SV-11. This effectively removes gas as a constraining item on the number of camera operates.

CONCLUSIONS

9. a. The basic precept of eliminating subsystem failure modes and increasing overall system reliability has resulted in the ability to plan confidently for longer mission durations.

b. The HEXAGON vehicle is presently capable of flying for approximately 120 days with adequate confidence in the ability of the hardware to successfully operate for that period of time.

c. Incorporation of the pyro-battery modification will permit the option to plan HEXAGON missions which exceed 120 days.

d. The incorporation of new thrusters, extensive cross-strapping, improved piece-part selection, assembly and test procedures on SV-13, will allow HEXAGON mission planning to consider active mission durations of up to 180 days.

e. Various modifications in the consumables area are possible and coupled with longer mission durations, appear to be attractive and worthy of continued investigation.

f. Mission support software should continue to be examined and modified as appropriate, to maximize the results of long-life missions.

g. However, to achieve a contractually-guaranteed lifetime of up to 180 days, or even 120 days, would require additional funding and is not currently planned.