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

OFFICE OF THE DEPUTY DIRECTOR

September 4, 1969

Dr. McLucas,

The attached report of the HEXAGON Review Committee was used as the basis for the briefing given to the NRP Executive Committee on June 20, 1969. The report has been prepared for file to be available for later review.

F. Robert Naka

F. Robert Naka

Attachment
Report of the
HEXAGON Review Committee

REPORT OF THE HEXAGON REVIEW COMMITTEE

June 20, 1969

GENERAL

This survey of the HEXAGON Project responds to a DNRO request of June 4, 1969 to report to the NRP Executive Committee on June 20. The short but intensive review had the objectives of

> Assessing the probability that an initial HEXAGON launch date of December 1970 can be met
>
> Determining the confidence of mission success for initial HEXAGON launches
>
> Recommending to the ExCom a plan to optimize existing collection capabilities while minimizing cost.

The Committee consisted of Dr. F. Robert Naka, DDNRO designee, Chairman; [redacted] CIA/OSP--the HEXAGON Sensor Subsystem Project Office (SSSPO); and Col. Lewis S. Norman, Jr., Vice Director of SAFSP.

It was clear that in the time available the Committee should not attempt an exhaustive technical review of either the HEXAGON Project or of other projects which could provide a capability for a time-phased collection overlap. The Committee concerned itself with comprehensive evaluation of those aspects of the HEXAGON and other projects which were directly relevant to the review objectives.

CONCLUSIONS AND RECOMMENDATIONS

Upon completion of its study, the HEXAGON Review Committee reached the following conclusions:

The probability that the date of the initial HEXAGON launch will not be delayed in excess of one month is 50 percent, that the delay will not exceed three months is 75 percent, and that the delay will not exceed six months is 95 percent.

The confidence of mission success for individual initial HEXAGON launches is 75 percent.

In view of these circumstances, adequate collection overlap could be provided if CORONA launches were rescheduled from the currently planned

6 in FY 1970
6 in FY 1971

to

5 in FY 1970
5 in FY 1971
2 in FY 1972.

No new CORONAs need be bought at this time.

Supported by these conclusions, the Committee recommends that:

The HEXAGON Project be funded to the minimum level necessary to meet the December 1970 initial launch date.

The CORONA launch schedule be revised to provide for

5 launches in FY 1970
5 launches in FY 1971
2 launches in FY 1972.

The need for a buy of additional CORONA vehicles be reviewed in December 1969.

SATISFACTION OF COLLECTION REQUIREMENTS

The Committee first directed its attention to the United States Intelligence Board (USIB) collection requirements, specifically those for HEXAGON. In discussions with the NRO/SOC, it was noted that complete satisfaction of current USIB search requirements is not achieved by CORONA alone. Increased satisfaction could be provided by using a combination of CORONAs and GAMBITs; HEXAGON will provide near 100 percent satisfaction. It was not obvious, however, that the user community considered CORONA collection inadequate.

Most of the remaining CORONA vehicles in the inventory would have a mission lifetime approaching 20 days each compared with 15 now generally flown, therefore the mission lifetime of five of the remaining CORONAs is comparable to six or eight of the older CORONAs (approximately 100 mission days per fiscal? year). The Committee was convinced that their recommended change in the CORONA launch schedule (see page 2) would maintain the current level of search collection satisfaction and would extend the period of overlap with HEXAGON. The current HEXAGON and recommended revised CORONA schedules would then appear thus.

	CY 1970						CY 1971													
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F
Current HEXAGON						Δ			Δ			Δ			Δ					
Revised CORONA		Δ	Δ				Δ		Δ			Δ		Δ			Δ			

The recommended overlap satisfies several contingent situations involving schedule slips and/or unsuccessful flights. As long as the first successful HEXAGON flight occurs by September 1971 (a 9-month delay from December 1970), the overlap with CORONA will maintain the current level of search collection satisfaction. Extending the CORONA schedule by six months into FY 1972 will require [redacted] of FY 1972 funding. However, these funds would not be required should successful HEXAGON flights occur before all CORONAs have been launched.

The Committee also considered other steps to insure continuance of both search and surveillance collection:

A contingent buy of new CORONAs

Refurbishing and flying the remaining GAMBIT (KH-7) payloads

Buying one or two additional of the current GAMBIT (KH-8) series, flying them at high altitudes against the HEXAGON surveillance targets (with worst resolution equivalent to the best achievable with HEXAGON), and concentrating the remaining CORONAs against the most difficult to satisfy requirement--that of semiannual in-bloc search.

The latter alternative virtually fully satisfies collection requirements. It would cost an estimated [redacted] in FY 1971 for additional vehicles. The seven vehicles in the current program for FY 1970 are in part to provide a backup capability for the GAMBIT Vehicle 23 configuration. If Vehicle 23 is a success, one or more of the FY 1970 GAMBIT vehicles can be flown at high altitude. (No change in the GAMBIT camera is required if photos are taken at altitudes of 110 nautical miles or below. Flights above 110 nm would require a modest one-time change to the camera to extend the operating range of the slant range compensator and of the film drive speed. This cost is estimated at [redacted].) However, as GAMBIT was designed as a surveillance and technical intelligence collector, its camera is not suited to search as are the CORONA and HEXAGON pan cameras. To satisfy both search and surveillance requirements would require continuing CORONA. This option best satisfies a situation where HEXAGON is not used.

The second option, flying the older GAMBIT series payloads, would involve major costs and require at least 19 months' lead time. The Satellite Control Network would have to be reoutfitted to track and command such a vehicle. New Age as and much out-of-production hardware would be needed. This option was considered clearly uneconomical and would not satisfy search requirements.

The first option is closely allied with the Committee's recommendation to revise the CORONA schedule to insure overlap.

If the revised schedule is adopted, reorder lead time for new CORONAs does not occur until December 1969. In the intervening time HEXAGON will have progressed through several major system level assemblies and tests, and we shall be in a much better position to determine whether a slip in HEXAGON will occur. Having had more testing time on the HEXAGON cameras, a better assessment of reliability could be made. The Committee urges that a decision to procure additional CORONAs be deferred until December 1969. Should a reorder be necessary, three units are estimated to cost a total of [redacted]; six units, [redacted]. [redacted] of FY 1970 funds would probably suffice to cover initial costs of either a three- or six-unit buy.

PROBABILITY OF MEETING A DECEMBER 1970 LAUNCH DATE

Sensor Subsystem (Perkin-Elmer)

The most critical, and indeed the pacing, HEXAGON component is the sensor subsystem. This Committee received detailed briefings at Perkin-Elmer, the sensor subsystem contractor, on progress in design, fabrication, and test. Of particular concern was the film transport system, the servo system, the thermal analysis of both the optical bars and the two-camera assembly, and the structural analysis. Perkin-Elmer has expended considerable effort in these critical areas. In particular, a thorough servo analysis, including the effects of structural and thermally induced disturbances, lends credence to Perkin-Elmer's conviction that successful operation of the sensor is highly probable. Thermal analyses were also exhaustive, resulting in a very good understanding of optical system performance. Work on the film transport system led to considerable refinement and simplification with consequent improved performance. The Committee also noted that in the six months since Dr. A. F. Donovan of Aerospace Corporation had conducted a systems engineering level audit of HEXAGON (at General Martin's request) informal assessment of HEXAGON sensor subsystem progress has been described as "remarkable." In general, the Committee was satisfied that the technical status of the sensor was indeed good.

The Committee also noted that, after considerable effort on the part of the SSSPO, Perkin-Elmer management had streamlined their internal functions to provide tighter and more effective technical management and cost control. The possible exception is in cost management of subcontractors.

The Committee found no major known problems with the sensor subsystem. Reliability causes continued concern, largely because of the number of electro-mechanical components of which the sensor is composed--many of which cannot be made redundant. Since near perfection through exhaustive testing is the only real approach to high reliability, the Committee believes continued priority emphasis here, as well as with electronic components, is essential.

Important, but of lesser concern, is the question of film properties. Film base thickness variations and film relative humidity pose difficult but, in the Committee's view, solvable problems.

Satellite Basic Assembly (LMSC)

The next most critical HEXAGON system element, the satellite basic assembly (SBA), was then examined. The SBA contractor, Lockheed Missiles and Space Company (LMSC), has had much experience in spacecraft design, manufacture, and test; and few unknown problems are expected. In the case of the SBA, problems are largely engineering in nature and several solutions are available.

The Committee did not consider reliability a major problem, for the SBA is composed of many components that can be made functionally or otherwise redundant. Certain components, such as the orbit adjust engine and the propellant tankage, are not redundant; but they represent current state-of-the-art and can be made demonstrably quite reliable.

Not so obvious are the incipient problems of operating the spacecraft as an entity. Past experience points to the probability that system problems will arise. Time is necessary for their resolution. LMSC, as satellite integrating contractor, is aware of this situation. LMSC and Perkin-Elmer must exhibit close cooperation if major system problems are to be avoided. System level engineering analysis and audit are lagging; should this continue, some system problems may be discovered in terms of damaged hardware from sneak circuits and unsuspected transients rather than from errors on engineering drawings. These circumstances are the greatest cause of uncertainty about meeting the established December 1970 initial launch date.

After considering all factors, the Committee is confident that with adequate funding HEXAGON can meet the initial

December 1970 launch date. As stated in the conclusions on page 2, the Committee agreed with the SSSPO evaluation of possible schedule delays. A lesser funding level would immediately produce a launch slip but no greater confidence in a firm initial launch date (for, though emerging problems might be solved during a schedule slip, there is no guarantee that the problems would reveal themselves in a timely fashion). However, only those aspects of the system associated with successful launch and operation of the basic sensor subsystem need be funded at levels necessary to achieve the December 1970 initial launch date. Other elements of the system (such as the terrain camera, associated integration costs, and its operational software costs) can be deferred without any effect on the basic HEXAGON vehicle.

CONFIDENCE OF MISSION SUCCESS

Factors assuring success of the first HEXAGON missions are wedded to those factors assuring achievement of a specified initial launch date. However, before a useful estimate of all-system success can be determined, it is necessary

To examine each major system element for its impact on probable mission success

To assess the critical technology

To evaluate expected launch and flight conditions.

Sensor Subsystem

The sensor subsystem represents the greatest advance in new technology. It is a complex redundant mechanism whose successful operation depends on excellence of functional design and thoroughness of testing. Its most critical components--those associated with the film transport and its allied servo system--are of new, untried designs. We believe the intensive attention given to these system aspects imparts a high confidence of successful operation. The Committee assesses the single shot probability as 88 percent that the sensor will survive the launch environment and operate for 30 days with acceptable optical performance--if not perfectly within specification.

Satellite Basic Assembly

The satellite basic assembly represents current state-of-the-art. However, it is an entirely new structure, containing some heretofore untried hardware--i.e., the propellant tankage with its gâlleried fuel lines. The basic structure is very long and quite flexible, both in torsion and bending modes. The film supply mounting is statically indeterminate, which defeats rigid structural analysis. Hence, a thorough testing program of flight-quality hardware is essential to structural integrity and to determination of modes of structure movement which might be coupled into the sensor. Fortunately, guidance and control, telemetry, command, power (including solar arrays), and orbit adjust engine have had (or will have) considerable prior flight experience. These systems also are more amenable to functional redundancy. Based on these factors, the Committee assessed the single shot probability that the satellite basic assembly will survive the launch environment and operate acceptably for 30 days in orbit as 90 percent (probably conservative).

Launch Vehicle

The launch vehicle, Titan IIID, is a different configuration of the Titan booster family; its major difference is that the Titan transtage is not used. Other components of the Titan IIID have been thoroughly flight tested and proved. Because of past experience with the launch vehicle, the Committee assesses the single shot probability of successful Titan IIID operation throughout the launch phase as 95 percent (probably conservative).

Recovery Vehicle

The final essential element is the successful functioning and recovery of each recovery vehicle (RV). The HEXAGON RVs are new, but are a scaled up "DISCOVERER" shape. The parachute design has been flown on the PRIME Project and will be scaled for the HEXAGON recovery vehicles. An extensive test program is under way, including high altitude drop tests to simulate all recovery sequences occurring after initial re-entry. Again using experience as a basis, the Committee assesses as 98 percent the single shot probability that each individual recovery vehicle survives the launch environment, operates successfully in orbit for its particular specified lifetime (the last RV must operate 30 days in orbit), and is successfully recovered.

General Mission Success

The Committee calculates as 75 percent the single shot probability that each individual HEXAGON vehicle will survive launch, operate acceptably for 30 days on orbit, and have successful first RV recovery. The assessment for all four recovery vehicles places the probability of success closer to 70 percent. (This latter figure is not directly equatable to mission success in terms of product returned because the first recovery vehicles generally bring back the majority of critical targets as a consequence of target priorities.) The Committee finds that the 75 percent probability figure is for all intents identical with the HEXAGON Project specified probability requirement.

Initial HEXAGON Mission Success

For the initial HEXAGON launch, what is the probability of successfully recovering good photographs in the first RV? The first HEXAGON vehicle will be operated under conditions tending to improve probability of mission success and to provide for recovery of the most significant information; thus, a comprehensive grasp of vehicle performance can be gained. Specifically, the first vehicle will be placed in a "benign" orbit--one which will not task the thermal control system and which has a sufficiently high perigee so that no orbit-sustaining maneuver will be required prior to recovery of the first RV. The first RV itself will be fully instrumented so that its performance can be carefully measured. Under serious consideration is programming the cameras so that film is transported in the forward direction only (and not reversed as is normal between each photo operation). Although some film would not be exposed under these circumstances, there is less chance of a film transport malfunction. This technique would be added insurance that some exposed film would be returned so that actual camera performance on orbit can be measured. Once the first re-entry vehicle is recovered, the film transport system could be operated in the normal forward and reverse cycle and other operations, such as orbit adjust, could be begun. The first few flights will not carry the terrain camera, and the additional weight-carrying capacity will be utilized by the installation of extra batteries. This will help guard against solar array malfunctions and provide sufficient power to insure return of the first re-entry vehicle with its load of film.

The Committee assigned no percentage probability to these techniques, but it is quite clear that they enhance the likelihood of successful return of exposed film in the first recovery vehicle.

EFFECT OF FUND LIMITATION

The Committee examined the situation which would arise should HEXAGON be funded in FY 1970 at a level less than that recommended. The sensitive element of the system is the sensor. If reduced [redacted] below the requested amount of [redacted], a six-month program slip would be expected. A [redacted] reduction would result in a twelve-month slip. Other elements of the system which are not pacing at this time appear to be as sensitive to reductions as does the sensor, but definitive figures were difficult to develop. However, the Committee agrees that a combined [redacted] reduction in satellite basic assembly and satellite integrating contractor funding (both LMSC) would result in a six-month slip. The amount of reduction leading to a twelve-month slip was not clearly identified, and considerable work on the part of the contractor would be necessary to develop credible figures. However, in the Committee's view, the launch date sensitivity to funding limitations had been tested enough to expose the problem adequately so no further exploration was conducted. It was evident that fund limitations would have an immediate, unfavorable effect on scheduling.

SUMMARY

Funding at the level required to achieve a December 1970 initial launch date is the preferable option. The probability of a successful HEXAGON flight by the third launch, June 1971, is close to 95 percent under these conditions. The pressure on the collection overlap can be relieved by stretching CORONA launches six months into FY 1972. This would entail expenditures of [redacted] in CORONA launch and operating costs in FY 1972, which may not actually be needed if HEXAGON flies successfully prior to our committing the last two CORONAs to flight. Immediate pressure on FY 1970 funds for a new CORONA buy can be relieved by deferring a decision until December 1969 at which time a more accurate assessment of the HEXAGON program can be made.

The Committee feels strongly that its recommendations are proper at this time. However, the Committee urges that the status of both CORONA and HEXAGON be carefully tracked in the next few months so that any departure from expected conditions can be quickly identified and a new course of action formulated. Such departures might take the form of a major technical problem in HEXAGON which would force a major slippage or any situation which would cause CORONA to be flown at more frequent intervals than those recommended. In any case, a clear determination should be made in December 1969 on whether to initiate a further CORONA buy.

F. Robert Naka

F. Robert Naka
Chairman

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Access to this document will be restricted to those persons cleared for the specific projects;

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

OFFICE OF THE DEPUTY DIRECTOR

March 3, 1970

MEMORANDUM FOR THE HEXAGON REVIEW COMMITTEE

SUBJECT: Discussion Section for the Second Report of the HEXAGON Review Committee

REFERENCE: Second Report of HEXAGON Review Committee, BYE-13478-69, dtd November 4, 1969

The attached Discussion Section for the Second Report of the HEXAGON Review Committee is transmitted for your records. You will note that this is the document cited under "Sources of Data" on page 2 of the reference.

The discussion section to accompany the Third Report of the HEXAGON Review Committee (BYE-12546-70, dated January 22, 1970) has been issued under separate cover by [redacted]'s office as BYE-7524-70, dated February 27, 1970.

Bob

F. Robert Naka
Chairman
HEXAGON Review Committee

Attachment
BYE-13479-69, Same Subj.

Distribution
1 Col. Norman
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November 4, 1969

MEMORANDUM FOR FILE

SUBJECT: Discussion Section for the Second Report of the HEXAGON Review Committee

REFERENCE: Second Report of HEXAGON Review Committee, BYE-13478-69, dtd November 4, 1969

Of the copious amount of data made available to the HEXAGON Review Committee, the following are some of the key items impacting on the conclusions:

1. <u>LMSC</u> (SBAC/SVIC)

a. <u>Schedule.</u> Many key milestones due to have been completed since last June have been met on their scheduled completion dates. Others, like the static test vehicle and the dynamic test vehicle, have slipped from three weeks to seven weeks but have not impacted on the initial launch date. Although Phase I of the satellite development vehicle (the system qualification and pad checkout unit) is about three weeks behind schedule, LMSC felt that the third and final phase would be on schedule. The delivery of the midsection for the first flight unit will probably be two and one-half weeks late, but again LMSC felt that the time was recoverable. The black box qualification program showed an extremely heavy concentration of effort during the October 1969 time period. The SDV-3 aft section module showed also a heavy assembly and test impact during the October to November 1969 period as did the first flight unit's aft section module during December 1969 and January 1970. The current two-shift operation at LMSC was felt to be adequate for this work load.

b. <u>Reliability.</u> LMSC reported the following status on their reliability analysis:

(1)	Parts Stress	80% Complete
(2)	Failure Mode & Effects	70% Complete
(3)	Worst Case	20% Complete

c. Problem Areas. The following includes both Committee and LMSC suggested problems as of this time:

(1) The active thermal control in the forward section was introduced into the system design at a fairly late date and was the result of Perkin-Elmer's end-to-end gradient requirement to avoid film sticking. Qualification of the temperature control electronics assembly is due to be completed in February 1970 and is clearly the pacing element of the SDV-3 forward section.

(2) The master/slave PCM multiplexer subcontractor [redacted] had exhibited difficulties to date in meeting performance and schedule. LMSC feels that this Q. A. problem has now been solved.

(3) The orbit adjust engine had experienced I_{sp} degradation during the deboost burn. Redundant heaters have been added for flight use to provide heating of the propellant; testing of this change is currently underway.

(4) The high failure rates of a certain solar array diode caused all of these diodes to be replaced with newer ones using improved techniques and processes. The new board design has been requalified and is now in reliability testing.

2. GE (Command Programmer)

a. Utica has solved the super flat pack production problem.

b. The minimal command system (MCS) is ahead of schedule. The extended command system (ECS) for SDV-3 had a minor low temperature problem but is due for delivery to SVIC on November 20, 1969. The ECS for the first flight unit is due for delivery on December 15, 1969 for a January 1970 need date.

3. TRW (Software)

a. A satisfactory Milestone 2 (preliminary design) was achieved on September 30, 1969 and contract awarded October 1, 1969.

b. Initial operational configuration is scheduled for September 25, 1970 with final operational configuration on September 10, 1971.

4. VAFB

a. The service tower has slipped three months, causing an equivalent slip in the beneficial occupancy date from October 31, 1969 to January 30, 1970.

b. Despite this fact, [redacted] feels that all the remaining key dates can be met:

(1) SDV-3 arrives at the pad on September 17, 1970 and is there for 54 work days.

(2) The launch complex acceptance is December 3, 1970.

(3) The first flight unit is on the pad ten days prior to the December 17, 1970 launch date (the booster has been at the pad since July 20, 1970).

5. McDonnell-Douglas (MWC)

a. The main parachute (made by Goodyear) is not as good as that used with the MK-5 RV. The ballute failed its deployment test (the requirement is a 60 to 70 percent probability of catch on the first pass), but the problem appears to be a Q. A. problem (and a difficult one) and not a design problem.

b. The B-52 and balloon drop test program is slightly behind schedule.

c. There is a relatively minor problem with access through the thermal "tent."

6. Perkin-Elmer (SSC)

a. Schedule.

(1) All of the tests scheduled for the engineering model have been satisfactorily completed except for those pending tests associated with Chamber "A," although completed later than originally scheduled.

(2) Completion of two-camera assembly testing on the development model is on schedule for November 19, 1969. The DM is plus eleven days against the scheduled February 20, 1970 ship date

because of the current 6-day, 10-hour per day work week. Many problem areas which have had schedule impact, like late delivery of key electronic boxes and compatibility problems with test equipment, have been solved through "work arounds."

(3) The first flight unit is on schedule to a January 27, 1970 completion of two-camera assembly testing and is also plus eleven days against its scheduled ship date to SVIC on April 21, 1970. Astigmatism caused by the folding flat has, in all probability, been resolved as was the longitudinal color problem on the first two sets of glass. Overtime and shortening of several remaining assembly and test cycle times, based on development model experience, would allow additional pad if there are any unforeseen schedule slip problems.

b. Reliability. About 2,000 electrical/mechanical functions and more than 30,000 items at the parts level have been evaluated to date. Only two or three truly random electronic failures have occurred to date on the engineering model. Catastrophic failure mode analysis has been extensive.

c. Problem Areas.

(1) The optical bar torque motor may be undersized because of the excessive friction of the rubbing optical bar seal needed for film path pressurization. The corrective action will be to use double commutation of motor windings as are now used in the drive capstans.

(2) Thermally induced local deformations in the folding flat, as well as the previously mentioned gravity-induced astigmatism, have caused some concern with regard to camera performance, but neither appears critical.

(3) The electronic box qual test program calls for an extremely concentrated effort in the November 1969 through March 1970 time period. Qual of four of the six brushless motors and the six encoders in the sensor subsystem between now and February 1970 is also tight.

7. CORONA

a. Current problems related to the reliability of UTB to be flown on future missions and the impact on reliability of the phase-down of the program.

b. The cost estimate for three additional systems if there were a reorder is as follows, assuming all three would be launched in FY 1972:

FY 1970	FY 1971	FY 1972	FY 1973	TOTAL
[redacted]				

based on a December 1969 go-ahead.

c. The minimum lead time from "go-ahead" to "first launch" of a reorder was as follows:

Main camera	23 months
DISIC camera	14 months
Agena	24 months
Thorad	24 months

d. Assuming a February 15, 1970 "go-ahead" for a February 15, 1972 launch (three months after the "last" CORONA) and a May 15, 1970 termination, about [redacted] would be non-recoverable.

e. The cost savings of not having to launch current CORONA vehicles during the planned one year of overlap is as follows:

Delete	Cumulative Cost Savings
CR-8 (Nov 71)	[redacted]
CR-8, 16 (Sept 71)	
CR-8, 16, 15 (May 71)	
CR-8, 16, 15, 14 (Mar 71)	
CR-8, 16, 15, 14, QR-2 (Jan 71)	

8. GAMBIT "HIGHBOY"

a. The following changes would have to be made to the existing GAMBIT configuration in order to fly in the "HIGHBOY" mode:

(1) Photographic Payload System.

(a) Film drive speed change affecting the metering roller diameter, the gear ratio, and the motor speed drive output.

(b) The drive range of the slant range compensator.

(c) The slit widths in the slit plate.

(d) The frequency of the ground scene modulation in the focus sensor.

(e) Additional thermal analysis which might require additional heaters.

(2) Satellite Recovery Vehicle. Change the backup timer.

(3) Satellite Control Section. Additional thermal analysis which might require additional battery capacity.

b. The following launch and delta cost options were presented, including both modifications and schedule revision effects:

Option	Launch (FY)			Cost (FY)			
	70	71	72	70	71	72	Total
1	0	1	0	[redacted]			
2	0	2	0				
3	0	1	1				

If the combined GAMBIT and [redacted] missions do not exceed twelve per year, there will be no launch facility impact.