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P-989

# COST BENEFIT STUDY

by

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This study will show that the P-989 Program is providing more sustained intelligence collection capability on-orbit for less cost than ever before in the history of the program. By comparison, the URSALA satellite system is now providing 20 times more intelligence data than a similar system available in 1968. In terms of constant dollars, the P-989 Program is currently funded at 80% of the FY 1968 budget, the lowest budget year since P-989 dollars have been separately identified. Further, this study will show that the P-989 Program is the most cost effective of the SAFSP programs in terms of cost per spacecraft pound per month of orbit life.

SECTION I

INTRODUCTION AND PURPOSE

This study will not attempt to place a value on the intelligence data being collected by P-989 satellites but will determine if they are a cost effective means of satisfying NRO intelligence requirements. This study will also determine if the trend towards more complex and costly P-989 (P-11) spacecraft has been cost effective.

## ANALYSIS APPROACH

### The Common Denominator

Historically, P-989 has been a multi-mission SIGINT program extending back to the first P-11 vehicle launched in March 1963. Because of the variety of SIGINT tasks (ELINT, COMINT, and TELINT) accomplished by these piggyback satellites it is extremely difficult to devise a common denominator by which to compare each spacecraft system and derive meaningful cost benefit trends. However, if the "dollar cost per spacecraft pound per on-orbit month realized" is derived, i.e., the cost per pound-month, we have a common denominator which addresses:

a. The cost of added complexity, i.e., for increased mission accomplishment or dexterity, in terms of total system weight.

b. The cost of reliability, i.e., added redundancy and increased pieceparts burn-in and screening, in terms of additional weight and extended life.

c. The cost of additional testing at all levels in terms of fewer infant mortality failures and extended spacecraft life.

It is recognized that the "dollar cost per spacecraft pound-month on-orbit" does not speak to the relative merits of the intelligence missions themselves nor to their subsequent accomplishment. However, it does provide a straight forward method for comparing satellite systems without requiring subjective decisions.

## Assumptions and Limitations

a. All hardware costs presented in this study are "price" to the Government.

b. All costs are compared in constant 1974 dollars, i.e., expenditures in previous years have been normalized to 1974 dollars using DOD escalation factors provided by [redacted] 25X1

c. Unit costs reflect the cost of the spacecraft hardware only.

d. This cost analysis considered only spacecraft costs back through FV 4410. Cost traceability and apportionment prior to FV 4410 is extremely difficult because prior spacecraft were assembled and tested under the SAFSP-7 launch services contract with Lockheed (LMSC) at Vandenberg AFB.

e. Where consideration of the two catastrophic failures, FV 4404 (14 May 66) and FV 4427 (11 Nov 71), would lead to erroneous trends the failure data has been factored out.

f. For the purpose of this analysis, all comparisons will reflect the actual spacecraft launch order. This causes the plot of on-orbit lives, Figure 2, in the era FV 4410 through FV 4421, to be more erratic than if the vehicles were plotted by contractural blocks or buys.

g. FV 4414/AZTEC I, FV 4415/AZTEC II, and FV 4416/CALSAT were research vehicles and not funded from P-989 resources. Although P-11 type spacecraft, they provide no relevant historical data because they were never launched.

h. Table 1 provides the data base for this study.

## Mission Duration

The accepted method of projecting the on-orbit life of spacecraft before

TABLE I

P-989 COST BENEFIT STUDY

DATA BASE

| FLIGHT VEHICLE | SPACECRAFT COST (PRICE) MILLIONS | COST IN 74 DOLLARS | SPACECRAFT WEIGHT (LBS) | ORBIT LIFE (MONTHS) | DOLLAR COST POUND-MONTH |
|---|---|---|---|---|---|
| 4410 | 1.7 | 2.3 | 228.4 | 3 | 3,325 |
| 4412 | 2.6 | 3.5 | 275.0 | 15 | 845 |
| 4411 | 2.6 | 3.5 | 284.9 | 12 | 1,019 |
| 4420 | 3.7 | 4.8 | 278.7 | 18 | 959 |
| 4413 | 2.4 | 3.1 | 259.7 | 12 | 1,001 |
| 4418 | 4.2 | 5.5 | 333.6 | 18 | 909 |
| 4417 | 3.5 | 4.6 | 364.7 | 10 | 1,248 |
| 4419 | 3.7 | 4.6 | 319.3 | 20 | 730 |
| 4407 | Unk | -- | -- | -- | -- |
| 4422 | 4.0 | 5.0 | 343.5 | 20 | 734 |
| 4421 | 4.4 | 5.5 | 333.4 | 33 | 504 |
| 4423 | 8.2 | 9.8 | 333.5 | 40 | 770 |
| 4427 | 10.1 | 12.0 | 373.3 | 1 | 32,025 |
| 4424 | 8.7 | 9.9 | 380.1 | *31 | 842 |
| 4425 | 8.2 | 9.4 | 390.8 | *31 | 772 |
| 4426 | 8.2 | 9.4 | 393.2 | *31 | 767 |
| 4428 | 6.0 | 3.3 | 381.0 | *48 | 361 |
| 4429 | 13.3 | 13.8 | 566.1 | *48 | 509 |
| 4430 | 14.7 | 15.0 | 571.7 | *48 | 546 |
| 4431 | 9.4 | 9.8 | 571.7 | *48 | 356 |

* Projected at twice MMD (See Section II - Mission Duration)
NOTE: Average actuals for FV 4421, 4422, and 4423 of contract block FV 4421 - FV 4427 is 31 months

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launch is by computation of a Mean Mission Duration (MMD). The MMD is computed from a piecepart count, failure rate estimates, and a reliability model tailored to the individual spacecraft. The MMD for the current block of P-989 spacecraft in orbit is 15.5 months, i.e., for FV 4421 through FV 4427. However, the average demonstrated orbit life for this block of vehicles (excluding FV 4427) is 31 months or twice their MMD. FV 4424, FV 4425, and FV 4426, having already survived the one month infant mortality of FV 4427, are assumed to have on-orbit lives equal to the 31 months. Also, for the purpose of this study, the projected life of the current block of spacecraft in development, i.e., FV 4428 through FV 4431, will be assumed to be twice their computed MMD or 48 months.

The fact that the average life appears to be twice the MMD is more complex than drawing the simple conclusion that the reliability model is too conservative. The MMD is based on the truncation of the system reliability curve. The truncation point for P-989 satellites is determined by the life of the tape recorder complement on board the spacecraft. Therefore, the MMD is sensitive to the cycle life assigned to each tape recorder and an assumed use rate in terms of minutes of mission tasking that will be accomplished per day. Also, three phenomena are occurring which are difficult to quantify for MMD computation but nevertheless are extending the life of the P-989 spacecraft. First, "third buy" tape recorders currently in spacecraft on orbit are exhibiting longer than expected cycle lives with each passing day. Second, as more spacecraft are launched there is greater competition between vehicles for tasking allocations. The newer vehicles historically get the "lion's share," which significantly reduces the use of the older vehicles, and extends their operational life. Finally, as the older spacecraft degrade, more and more mission tasking must be consumed just to maintain their health. This further reduces tape recorder usage and extends the useable life of the spacecraft.

Finally, the projected life of 31 months and 48 months used in this study is defined to be that point where the "mission worth" of the P-989 spacecraft goes to zero. These numbers are not intended to be used for development/replenishment rate determinations since they are conditional estimates. That is, given the P-989 spacecraft successfully attains orbit and survives an infant mortality period, current indications are that it will last twice its MMD.

# SECTION III

## DISCUSSION

How did the P-989 Program get where it is today, i.e., developing fewer but more complex and costly systems?

### Why Fewer Systems

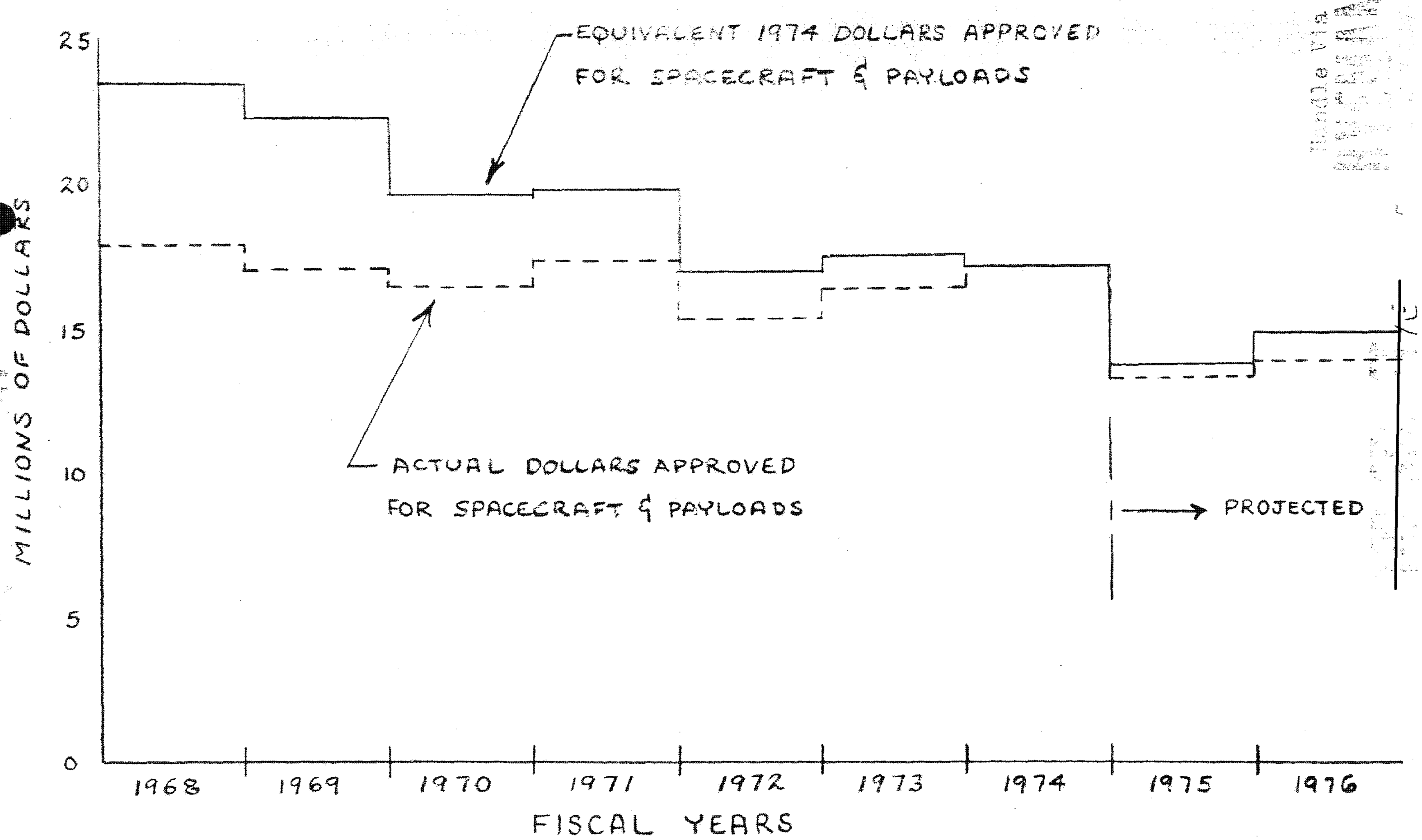
First, why are we developing fewer spacecraft? The answer is that with a budget ceiling imposed on the program each year and spacecraft costs increasing, there will be fewer systems. Figure 1 shows that portion of the P-989 budget that has been approved, by fiscal year. for "Spacecraft and Payloads." Also shown is the equivalent buying power of those dollars through the years. Therefore, while the actual dollars for spacecraft and payloads has remained reasonably constant, what can be bought with those dollars is some 30% less today than in 1968. (The P-989 budget was not separately identified prior to 1968.)

### Fewer Missions

Fewer spacecraft has certainly been the result of fixed dollars and increased costs but there is another underlying reason. Heretofore there has been a steady stream of SIGINT missions for the P-989 Program to accomplish. Today there are less missions because both the P-989 spacecraft and other collateral systems are individually satisfying a broader range of SIGINT requirements.

### Lasting Longer

Besides having fewer viable missions, the P-989 spacecraft are lasting




DOLLARS APPROVED FOR P-989 SPACECRAFT & PAYLOADS BY FISCAL YEAR

FIGURE 1

longer. The respective spacecraft months of on-orbit life has been plotted, Figure 2, in their chronological order of launch. From Figure 2 it can be seen that:

a. There has been a steady improvement in the orbit life of the P-989 spacecraft since 1967, FV 4410.

b. The life expectancy of each spacecraft has been much less erratic since FV 4410.

c. All spacecraft since FV 4410 have exceeded their design/performance incentive life of nine months, with the exception of FV 4427.

d. To date there has been a significant and demonstrated increase in the on-orbit life being realized from the current block of P-989 satellites, i.e., FV 4421, FV 4423, and FV 4424 (now 25 months old).

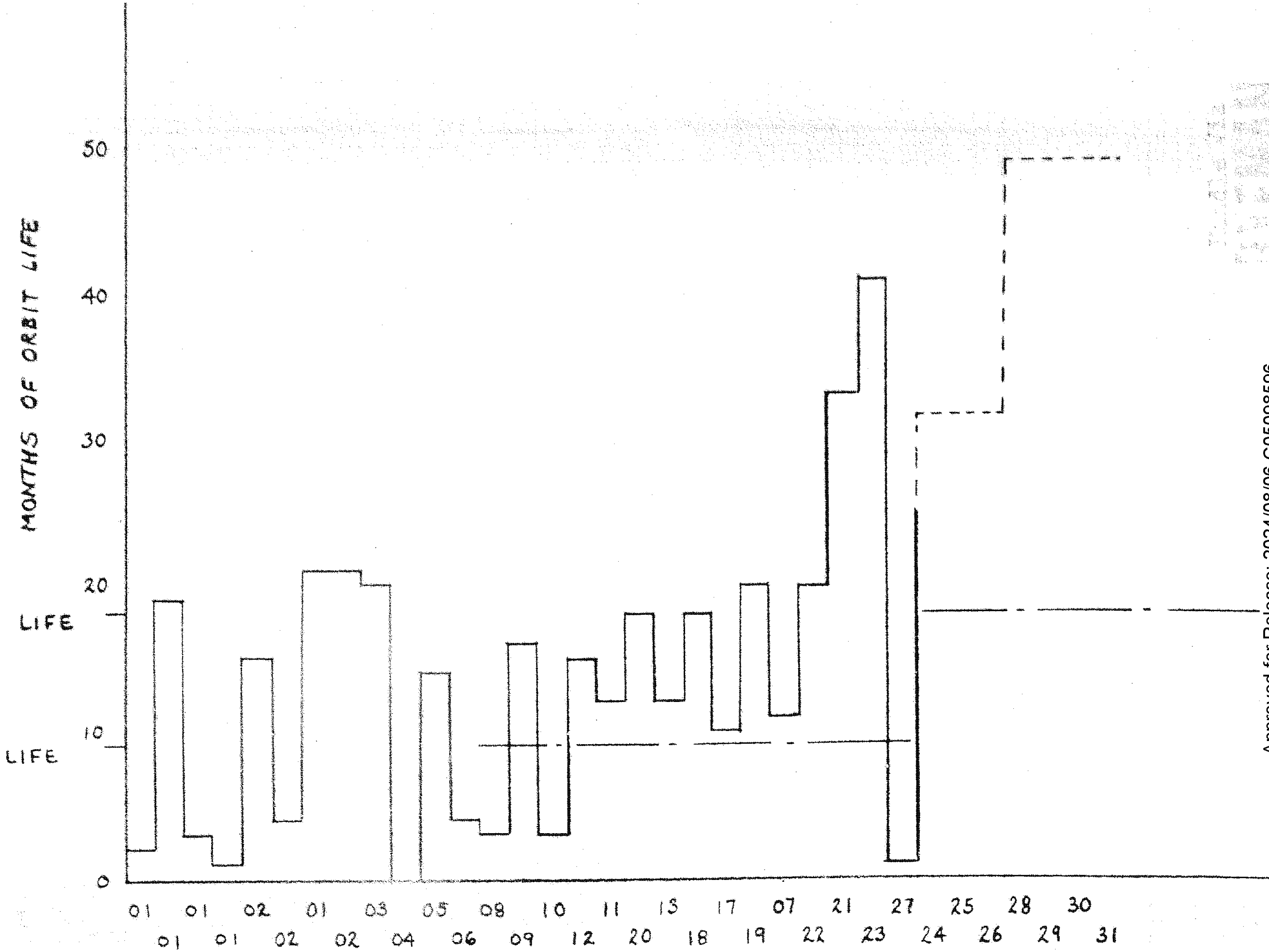
e. The projected/predicted on-orbit life of the future "Cast Iron P-11s," FV 4429 and up, is more than five times the original P-11 design life of nine months.

## Cost Growth

From Figure 3, three distinct cost growth steps are apparent, at FV 4418, at FV 4423, and at FV 4429. The first step can be attributed to (1) going Factory-to-Pad, (2) adding system level environmental testing, and (3) a P-11 vehicle block change.

The dramatic cost increase after FV 4421 can also be atributed to three major cost elements, (1) a technological capability/complexity jump with the introduction of integrated circuits, (2) conversion to the new host (P-467) booster vehicle, and (3) an increase in the component, subsystem and system level testing resulting from the first two.

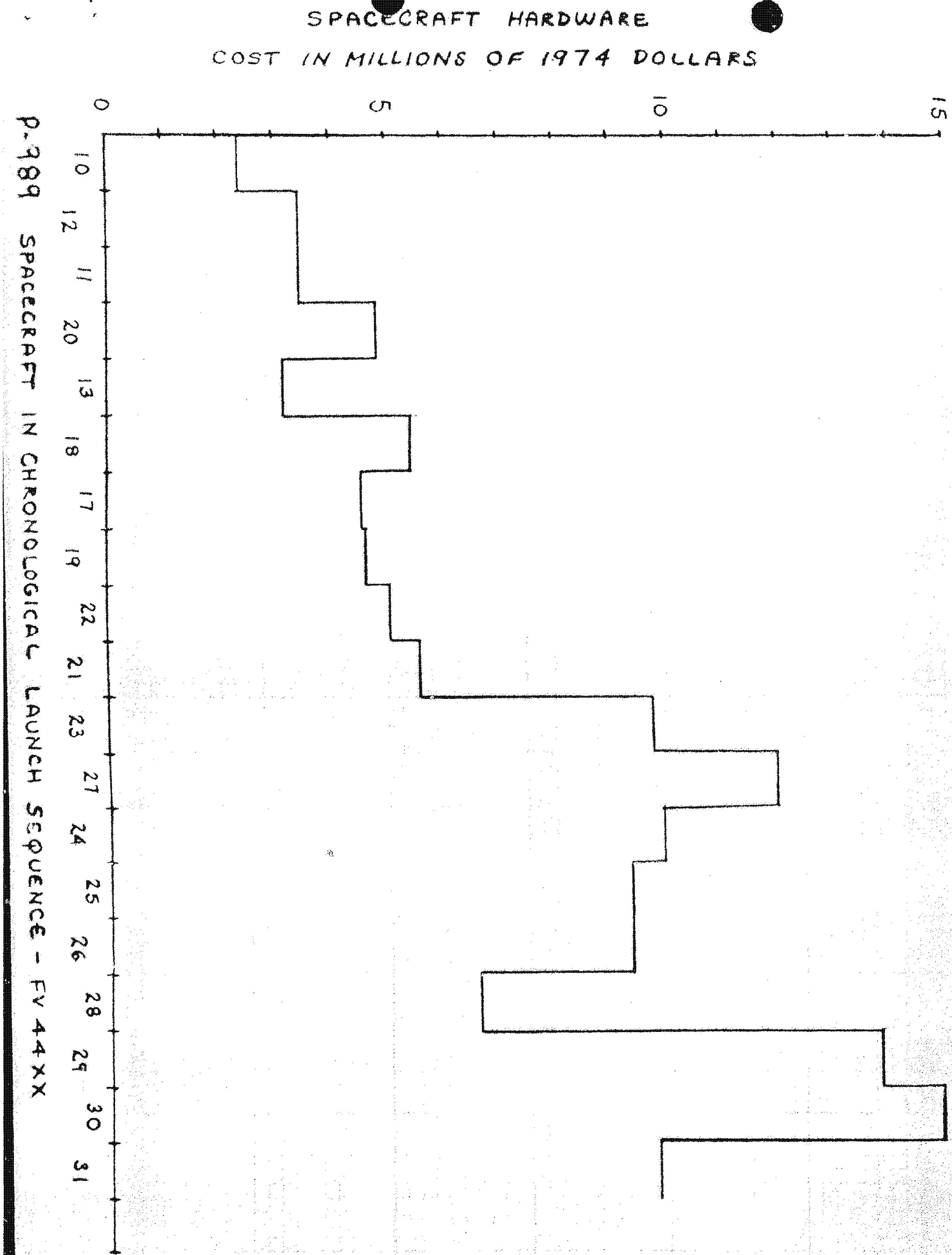
The last significant cost increase on Figure 3, commencing with RAQUEL




P-989 CHRONOLOGICAL LAUNCH SEQUENCE BY TAIL NUMBER - FV 44XX

THE FIRST SIX P-11'S WERE RESPECTIVELY

4201, 4001, 4101, 4301, 4202 & 4302


SPACECRAFT HARDWARE
COST IN MILLIONS OF 1974 DOLLARS
0
5
10
15
10
12
11
20
13
18
17
19
22
21
23
27
24
25
26
28
29
30
31
P-989 SPACECRAFT IN CHRONOLOGICAL LAUNCH SEQUENCE - FY 44XX

(FV 4429), can be attributed to the same basic cost elements addressed above. With the RAQUEL technical intelligence payload the capability/complexity costs took another step upward. This increase in payload cost includes not only the move to HI-REL pieceparts and complementary metal oxide semiconductor (CMOS) technology but added redundancy and additional payload subassembly and subsystem level testing. The basic spacecraft was also upgraded to HI-REL pieceparts in conjunction with an upgrade of the major spacecraft utility subsystems. This upgrade constitutes the P-989 vehicle block change (FV 4429 and up) nicknamed "the Cast Iron P-11." See Table 2 for a comparison of the Cast Iron P-11 with the current vehicle configuration.

Finally, Figure 3 also shows the cost savings when "repeat" missions/payloads occur, i.e., TOPHAT I/FV 4423 vs TOPHAT II/FV 4428 and URSALA III/FV 4430 vs URSALA IV/FV 4431. Although from a cost standpoint "repeat" systems look cost effective this could be deceiving in the future. That is, when payloads are bought two at a time but launched serially, there is a risk that by the time the second payload is launched it will not satisfy the current SIGINT requirements. Modifications to subsequently upgrade the repeat payload to meet these requirements may be more costly than ordering a new system. (Note there have been other repeat payload buys. However, their costs were not separately identified which has obscured the resultant cost savings.)

## Cost Benefits

Having explored why there are fewer, more costly, and complex P-989 spacecraft the question of cost effectiveness remains to be answered. That is, have the benefits derived from this course of action been worth the incurred costs? From Figure 4 it can be seen that the "cost per pound of capability on orbit" has been decreasing and is projected to continue to

TABLE 2

CURRENT SYSTEMS VERSUS CAST IRON P-11

The following table shows the unique differences between previous P-989 spacecraft and the Cast Iron P-11:

| ITEM | PRESENT SYSTEMS | CAST IRON P-11 |
|---|---|---|
| Spacecraft | Through FV 4428 | FV 4429 and up |
| Design Life | 9 months | 18 mos |
| Weight | 400 lbs max | 600 lbs max |
| 3-Bay Configuration | Varies | Standard |
| Power Subsystem | | |
| Configuration | Varies | Standard |
| Batteries | 1 or 2 | 2 |
| Solar Modules | 90 | 140 |
| TT&C Subsystem | | |
| Type | UHF-FM/FM | SGLS |
| Command receivers | 1 | 2 |
| Decoders | 1 | 2 (equivalent) |
| Primary timers | 1 | 2 (equivalent) |
| Transmitters | 3 | 4 |
| Attitude Sensing Subsystem | | |
| Horizon Sensors | 1 or 2 | 2 |
| Solar Aspect Sensors | 2 or 3 | 4 |
| Shift registers | 1 | 2 (equivalent) |
| Attitude Control Subsystem | | |
| Electronic Control Package | 1 | 2 |
| Coils | 1 | 2 |
| Spin Rate Control Subsystem | 0 to 1 | 1 |
| Inertia Control Subsystem | Optional | Optional |
| Data Storage Subsystem | 3 ea 1 MHz or 150 KHz recorders | Same |
| Propulsion Subsystem | | |
| Orbit adjust motors | to 22 lbs | to 68 lbs |
| Spin rocket motors | 2 | 3 or 4 |
| Payload Subsystem | | |
| Weight | 105 lbs max | 150 lbs max |
| Volume | 3,500 $in^3$ | 5,500 $in^3$ |
| Reliability | | |
| Pieceparts | Commercial | MIL ER or better |
| Redundancy | None | Selective |

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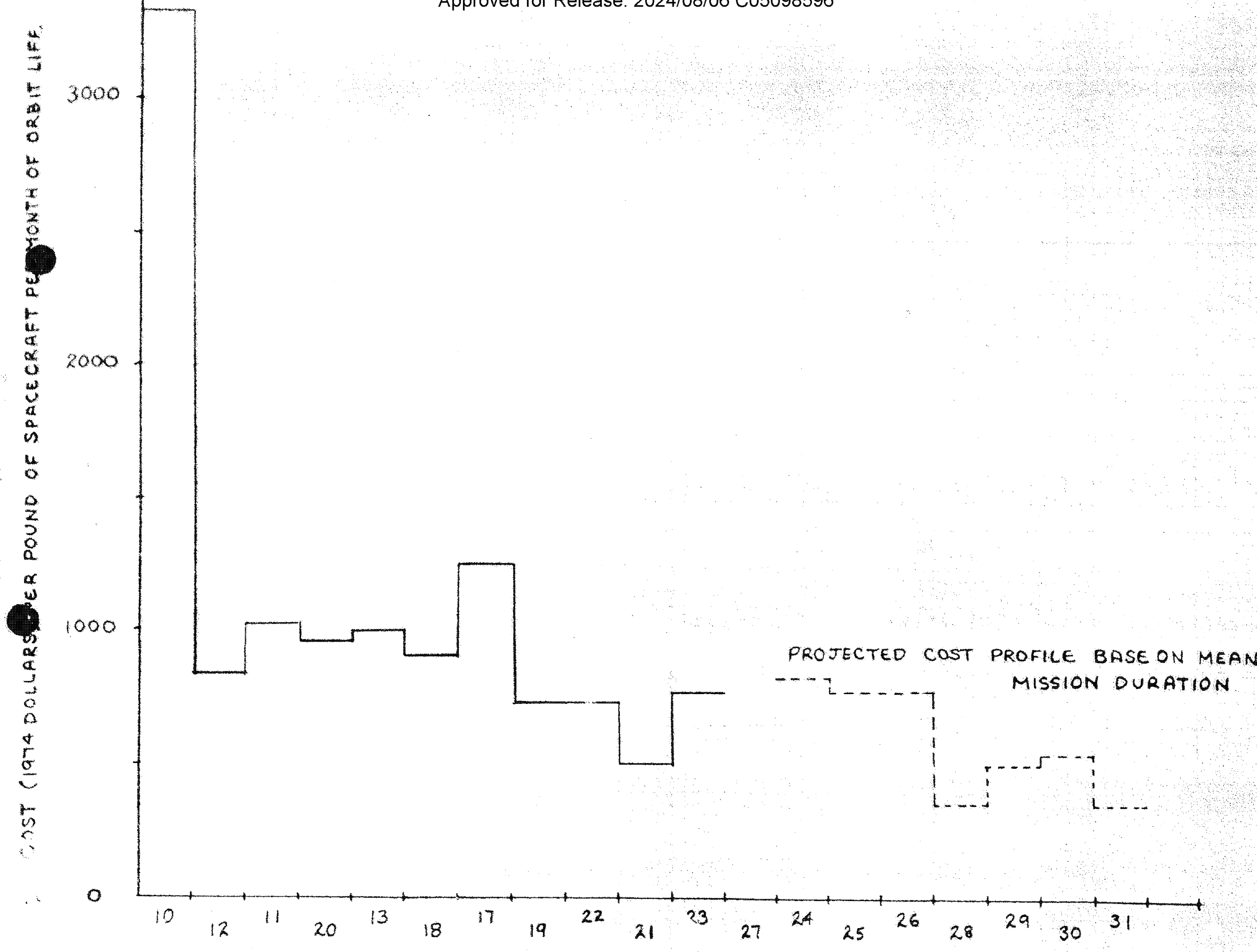


P-989 SPACECRAFT IN CHRONOLOGICAL LAUNCH SEQUENCE - FV 44XX decrease. Therefore, the payoff is: THE P-989 PROGRAM IS PROVIDING MORE AND MORE INTELLIGENCE CAPABILITY ON ORBIT FOR LESS COST THAN EVER BEFORE. Table 3 perhaps better illustrates this payoff, i.e., in terms of vehicle block changes or contractural buys.

To add further credibility or confidence in this payoff statement, the introduction and summary of a cost effectiveness study performed by the P-989 prime contractor (LMSC, [redacted]) will be presented below. The title of the study is "P-114 General Search and EOB Collection System Cost Effectiveness Study (S), [redacted] and is dated 2 May 1973. 25X1

> On 4 April 1973, [redacted] asked for a cost effectiveness study to be performed to show the degree to which the Air Force and other government users have benefited in the [redacted] SIGINT collection business in spite of the increasing complexity and cost of such satellite systems. This study has been accomplished by using as a measure of effectiveness the number of certified and qualified elint emitter locations obtained per thousand dollars spent for both spacecraft and ground processing. The study shows that a steadily increasing return to the government has been enjoyed ranging from less than four confirmed emitter locations per thousand dollars achieved by Spacecraft 4421/TRIPOS-SOUSEA, designed using 1969 technology, to more than 63 confirmed emitter locations per thousand dollars expected to be experienced with Spacecraft 4431/URSALA IV, based upon 1972 technology. The exact progression is shown below:

| SPACECRAFT | LAUNCH YEAR | CONFIRMED EMITTERS PER $1,000 |
|---|---|---|
| 4421/TRIPOS-SOUSEA | 1970 | 3.3 |
| 4425/URSALA I | 1972 | 32.6 |
| 4430/URSALA III | 1974 | 43.9 |
| 4431/URSALA IV | 1975/1976 | 63.9 |

Granted there are dispersions about these numbers induced by normalizing the raw data but taken at face value, URSALA IV is projected to be 20 times more effective than TRIPOS-SOUSEA at only twice the system cost.

This increase in cost effectiveness is also confirmed by the fact that all P-770 and P-989 intercept data were originally processed on a CDC 6400 computer. As the volume of P-989 data increased a CDC 6600 computer

TABLE 3

## AVERAGE COST PER SPACECRAFT POUND

## PER MONTH OF ORBIT LIFE BY CONTRACT BLOCK

| CONTRACT VEHICLE BLOCK | FV 4410 4411 4412 4413 | FV 4417 4418 4419 4420 | FV 4421 4422 4423 4424 4425 4426 4427 | FV 4428 4429 4430 4431 *4432 *4433 |
|---|---|---|---|---|
| Average Cost (1974 dollars) | 3.1M | 4.9M | 8.7M | 11.3M |
| Average Spacecraft Weight (lbs) | 262 | 324 | 364 | 523 |
| Average Payload Weight (lbs) | 63 | 70 | 89 | 129 |
| Average Orbit Life (months) | 10.5 | 16.5 | 31** 28.3 | 48*** |
| Average Cost per lb-mos (74 dollars) | 1,127 | 917 | 771 858 | 450 |

* Kits only (no missions - not included in averages)

** Based on FV 4421, 4422, and 4423 actuals (See Section II - Mission Duration)

*** Projected at twice MMD (See Section II - Mission Duration)

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was required to process both the P-770 and P-989 data. Since the phase out of the P-770 Program and subsequent launch of more capable P-989 spacecraft, the CDC 6600 has had to be replaced by a CDC Cyber 74 computer to gain additional processing speed and capacity.

## Cheap P-11s

But what about this increased capability - has it really been necessary? Experience tells us that the minimum standard (capability) is always the existing one. That is, an old TIVOLI Technical Intelligence system or the TRIPOC-COUSEA General Search system would not be approved today having respectively a RAQUEL and URSALA III available. The reason is their capabilities would not satisfy the current ELINT requirements as derived from the PEG (Priorities for ELINT Guidance) or the Five Year Plan. For a comparison of capabilities, old and new, see Table 4.

Pursuing this point further, the question arises as to whether a cheap P-11 or P-989 spacecraft could be built today. The answer is yes if we are willing to accept a system like FV 4420 at five million, in 1974 dollars, and:

a. A payload with 20 times less capability (70 lbs vs 150 lbs)

b. Reduced geopositioning (15 nm vs five nm over a 650 nm swath)

c. Reduced on-orbit life (16 mos vs a projected 48 mos)

d. Commercial pieceparts (infant mortality failures)

e. No redundancy (catastrophic failures)

f. Reduced system level environmental testing (workmanship failures)

g. Reduced tasking (168 minutes per day vs 348 minutes per day - best case)

TABLE 4

PAYLOAD SYSTEM IMPROVEMENTS

| | 1968 | 1974 |
|---|---|---|
| ITEM | TRIPOS/SOUSEA FV 4420 | URSALA III FV 4430 |
| DF System | Centroid only [redacted] | Monopulse [redacted] |
| Frequency Accuracy | ± 30 MHz | ± 2 MHz |
| Frequency Coverage | 4 to 12 GHz | 2 to 12 GHz |
| Per readin | 4 GHz | 6 GHz |
| Instantaneously | 670 MHz | 2 GHz |
| Sensitivity | -90 dbm (typical) | -100 dbm (typical) |
| Data Handling | Asynchronous (fragmented) | Full PCM (simpler processing) |
| Max readin Capability (per recorder) | 12.5 min | 24 min |

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h. No attitude control system

i. No spin rate control system

j. No advanced command system (39 discretes vs 3,000 discretes).

It is this author's opinion that these are not viable give back items.

Cost Comparison

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25X1

P-989 Advantages

The advantages of the P-989 low altitude SIGINT reconnaissance program ilies in maintaining:

a. The flexibility to respond quickly to user needs and changing requirements.

b. High emitter location accuracy.

c. The ability to intercept, locate, and measure low power emitters.

d. The ability to intercept and make parametric measurements in target emitter main beams.

e. The ability to electronically search any area on the earth's surface.

f. The ability to routinely provide certified intelligence data in less than six hours.

SECTION IV

CONCLUSIONS

1. The P-989 Program is providing more sustained intelligence capability on-orbit for less cost than ever before in its 11 year history.

2. The P-989 spacecraft is a sophisticated intelligence collection system that has evolved in response to more demanding user needs and changing NRO requirements.

3. The trade off decisions to stay abreast of the state-of-the-art in electronic technology, test and reliability have been cost effective. There should be no turning back.

4. The P-989 Program has demonstrated that it can consistantly provide a cost effective SIGINT satellite system to satisfy NRO requirements.