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Copy A of 3
Page 1 of 3

Pro-B-1-C(2)

13 MAY 1974

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FROM: [redacted] (Simonton/[redacted]

SUBJECT: P-989 Cost Growth History

TO: SAFSS [redacted]/Feldman)

1. Reference WHIG 0568 dated 2 May 1974.

2. Table 1, entitled "P-989 Cost Data Base," provides spacecraft cost and weight growth data. Regarding this data:

a. All costs are price to the government.

b. 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. The cost incurred to perform this work was not separately identified.

c. For cost comparison, spacecraft costs are also provided in constant 1974 dollars, i.e., expenditures in previous years have been normalized to 1974 dollars using DOD escalation factors provided by [redacted]

d. The spacecraft cost in constant 1974 dollars is based on the escalation factor for that fiscal year in which the majority of the work on the spacecraft/payload system was accomplished.

e. FV 4414/AZTEC I, FV 4415/AZTEC II, and FV 4416/CALSAT were research vehicles and not funded from P-989 resources.

TABLE 1

P-989 Cost Data Base

Flight Vehicle (FV)	Spacecraft Cost (Price) Millions	Cost in 74 Dollars	Spacecraft Weight (lbs)	Orbit Life (Mos)	Launch Date
4410	1.7	2.3	228.4	3	2 Nov 67
4411	2.6	3.5	284.9	12	14 Mar 68
4412	2.6	3.5	275.0	15	24 Jan 68
4413	2.4	3.1	259.7	12	18 Sep 68

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Flight Vehicle (FV)	Spacecraft Cost (Price) Millions	Cost in 74 Dollars	Spacecraft Weight (lbs)	Orbit Life (Mos)	Launch Date
4417	3.5	4.6	364.7	10	1 May 69
4418	4.2	5.5	333.6	18	19 Mar 69
4419	3.7	4.6	319.3	20	22 Sep 69
4420	3.7	4.8	278.3	18	20 Jun 68
4421	4.4	5.5	333.4	33	20 May 70
4422	4.0	5.0	343.5	20	4 Mar 70
4423	8.2	9.8	333.5	*41	18 Nov 71
4424	8.7	9.9	380.1	*27	20 Jan 72
4425	8.2	9.4	390.8	*22	7 Jul 72
4426	8.2	9.4	393.8	* 6	10 Nov 73
4427	10.1	12.0	373.3	1	10 Sep 71
4428	6.0	6.6	381.0	* 1	10 Apr 74
4429	13.3	13.8	566.1	**TBD	-
4430	14.7	15.0	571.7	**TBD	-
4431	9.4	9.8	571.7	**TBD	-

* Currently operational - months on orbit to nearest full month as of 1 May 1974

** To be determined - Mean mission duration is 24 months

3. Table 2, entitled "P-989 Spacecraft Growth by Contract Block," shows the P-11 growth in terms of average values across vehicle blocks. Note the decreasing cost per pound month of orbit life resulting from increased reliability.

TABLE 2

P-989 Spacecraft Growth by Contract Blocks

CONTRACT VEHICLE BLOCK	FV 4410 4411 4412 4413	FV 4417 4418 4419 4420	FV 4421 4425 4422 4426 4423 4427 4424	FV 4428 *4432 4429 *4433 4430 4431
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**	48***
Average Cost per lb-mos (74 dollars)	1,127	917	771	450

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

** Based on FV 4421, 4422, 4423, and 4424 actuals

*** Projected based on current experience vs computed mean mission durations

4. Attachment 1, entitled "Cost Growth of the P-989 Spacecraft," provides a brief history of the evolution of the P-11 vehicle into the sophisticated, complex and costly spacecraft of today.

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COST GROWTH OF THE P-989 SPACECRAFT

From Figure 1 four distinct cost growth steps are apparent. at FV 4411, at FV 4417, at FV 4423, and at FV 4429. The first step can be attributed to the cost of implementing the "Factory-to-Pad" concept. Prior to this time P-11 spacecraft were shipped to Vandenberg AFB in "Heath Kit" form and assembled and tested under the launch services contract with IMSC/VAFB. Hence the total transfer of the assembly and checkout of the P-11 vehicles to Lockheed, Sunnyvale, shows up as increased costs to the P-989 Program. Concomitant with the Factory-to-Pad concept was the desire to get out of the "skunk works" mode of building and testing P-11 vehicles. Figure 2 shows that the "skunk works" type of operation (pre-FV 4411) was not producing consistant launch and on-orbit success. The program test plan was therefore expanded to include system level thermal vacuum testing as well as other tests that were more in step with the other SAFSP programs. In short, approximately 10,000 more manhours were expended in test per spacecraft system which translated into higher unit costs.

Starting with FV 4417 the basic P-11 system capability was increased. The vehicle block change included going to two batteries, double foldout solar arrays and a re-designed basic structure for increased payload weight and volume. This structural change permitted a system weight increase of 65 pounds (285 to 350 lbs). This block change likewise increased the unit cost.

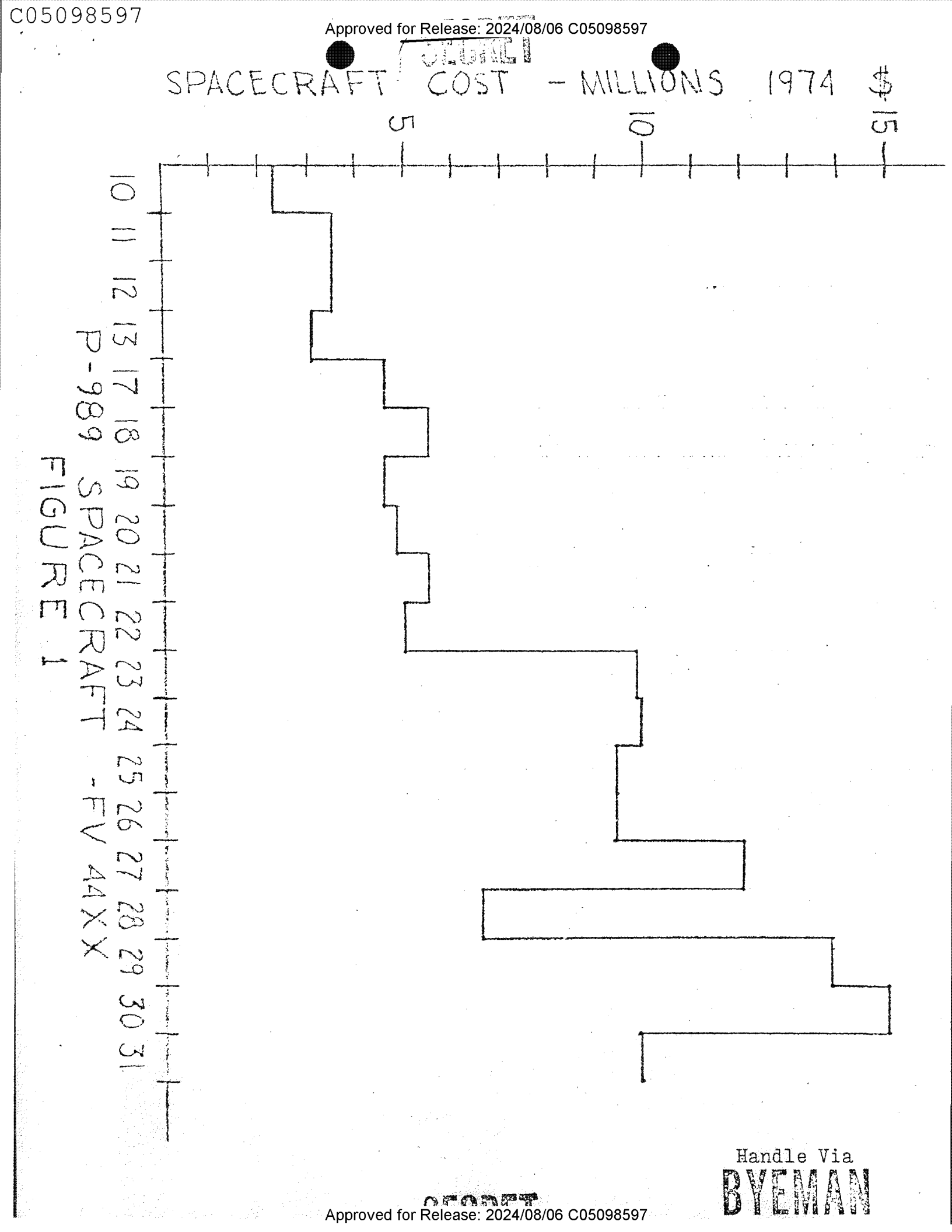
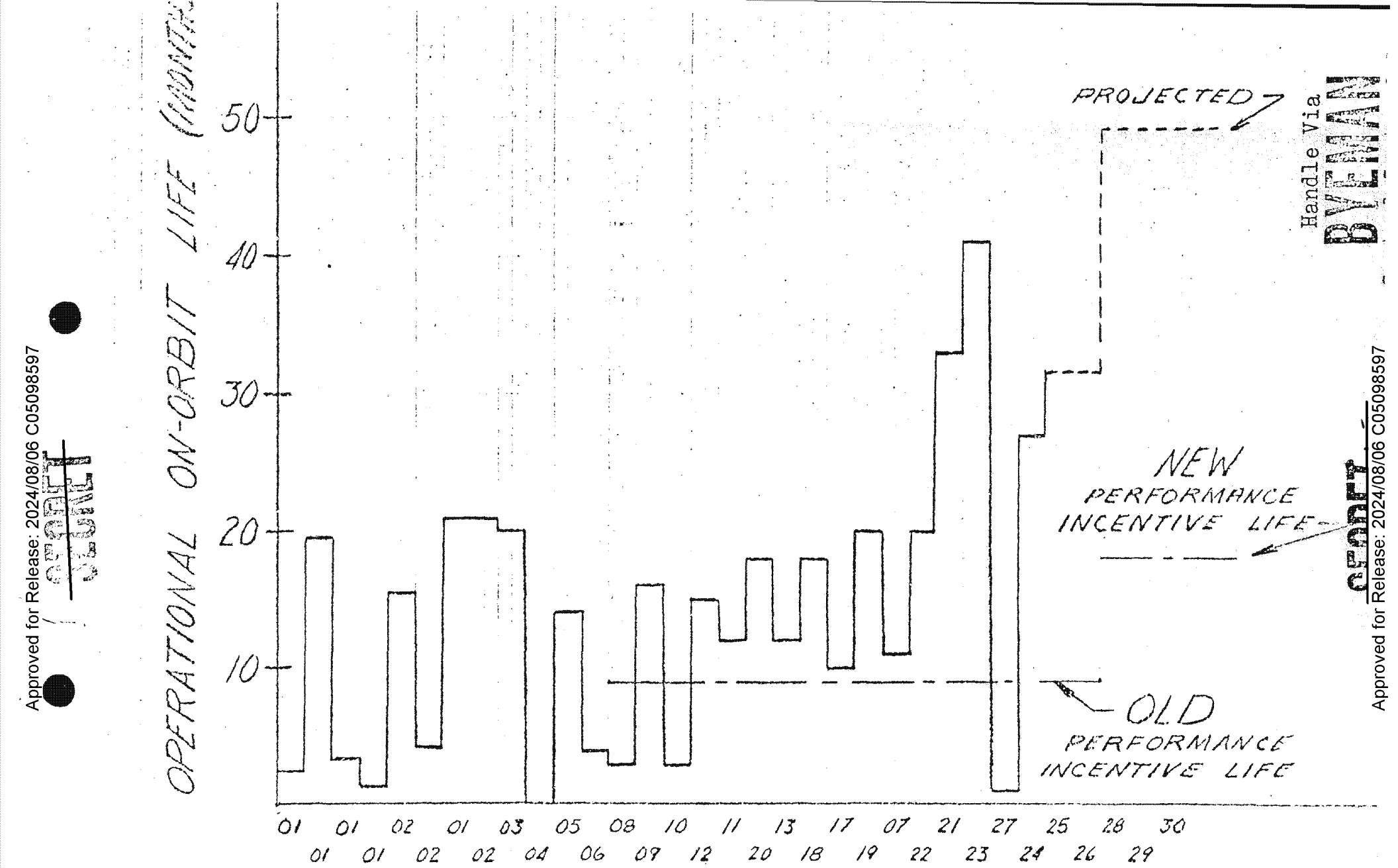


FIGURE 1



CHRONOLOGICAL LAUNCH SEQUENCE

NOTE: The first six were 4201, 4001, 4101, 4301, 4202 & 4302

The remaining are 44XX

FIGURE 2

In summary, the 240% cost growth between FY 4410/1967 and FY 4421/1969 was driven by (1) going Factory-to-Pad, (2) adding system level environmental testing, and (3) a P-11 vehicle block change.

The dramatic cost increase after FY 4423/1970 can be attributed to three major cost elements: (1) a technological capability/complexity jump made possible by 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 second battery, at this point, was replaced by a third 1 MHz tape recorder in an effort to extend the life of the spacecraft vis-a-vis the life limiting data storage subsystem. The technological capability/complexity jump for the most part occurred in the payload subsystem. This can be illustrated by comparing payload costs, i.e., the TIVOLI III Technical Intelligence payload (FY 4422) cost 0.8 million while the cost of the ARROYO COMINT mapping payload (FY 4427) stepped to 3.2 million. It was also at this time that the new series Electronic Order of Battle (EOB) systems were started, i.e., URSALA I/FY 4425 and URSALA II/FY 4426. The total cost of their two payloads was 3.4 million.

Conversion to the new host program, P-467, for piggyback rides required not only the development of a new launcher system and requalification of the spacecraft, but generated the requirement to modify the basic P-11 structure to be compatible with either the P-846 Agena (old host) or the P-467 Satellite Vehicle (SV) to assure the P-939 ride

availability during the transition period. These launcher development and spacecraft modification costs were amortized over the affected vehicles which further increased their unit cost.

In regards to testing, it was also at this time that the program test plan was expanded again due to the increased system complexity. The payloads had many more operational modes which had to be tested. Attitude and spin rate control systems were also added to the spacecraft which increased both component level and system level testing, i.e., another four to five thousand manhours were required per spacecraft for test.

The last significant cost increase on Figure 1, commencing with RAQUEL (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 up from ARROYO, at three million dollars, to five million dollars. This increased 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 move to CMOS technology was in recognition of the need to take another step in order to accomplish the RAQUEL mission and prepare for future user demands.

Further, the basic spacecraft was also upgraded to HI-REL pieceparts in conjunction with an upgrade of the major spacecraft utility subsystems. For instance, the present tracking, telemetry and command

system (TT&C) has been changed to a Space Ground Link Subsystem (SGLS). (P-989 is the last of the SAFSP programs to convert to SGLS.) Also, the basic spacecraft structure was redesigned to allow a system weight increase of 250 pounds (350 to 600 lbs). This upgrade constitutes a P-989 vehicle block change (FV 4429 and up) nicknamed "the Cast Iron P-11." See Table 1 for a comparison of the Cast Iron P-11 with the current configuration. This block change, which includes development and qualification costs, has been amortized over five spacecraft increasing their unit cost by approximately one million dollars. The program test plan has also been expanded to include more box level burn-in and a system level thermal vacuum test with twice the previous time at vacuum conditions.

Again, what was the driving force behind this block change? Basically it was the uneasiness of the times. In the fall of 1971 and spring of 1972, a number of major failures befell the SAFSP programs, i.e., the catastrophic ARROYO, [redacted] failures as well as major malfunctions with the P-110 and P-846 satellites. Resulting reliability reviews subsequently brought pressure to bear on the P-989 Program for (1) HI-REL pieceparts, (2) redundancy, and (3) a test program equal to the other SAFSP programs. Hence, a significant cost impact.

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Finally, Figure 1 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

TABLE 1

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 months
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	Selectable

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 then current SIGINT requirements. Modifications to subsequently upgrade the "repeat" payload to meet these requirements may be more costly than ordering a new system. (Note that there have been other "repeat" payload buys. However, their costs were not separately identified, which has obscured any resultant cost savings.)