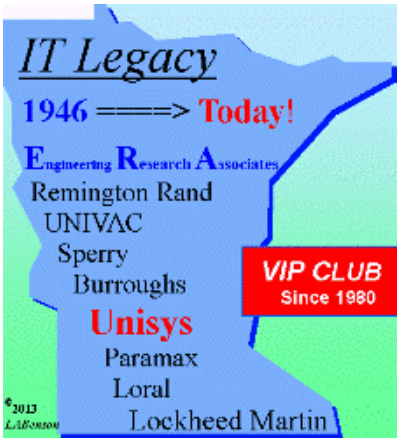
50 Years of Ocean Surveillance

An Information Technology Legacy Paper

Edited by Lowell A. Benson

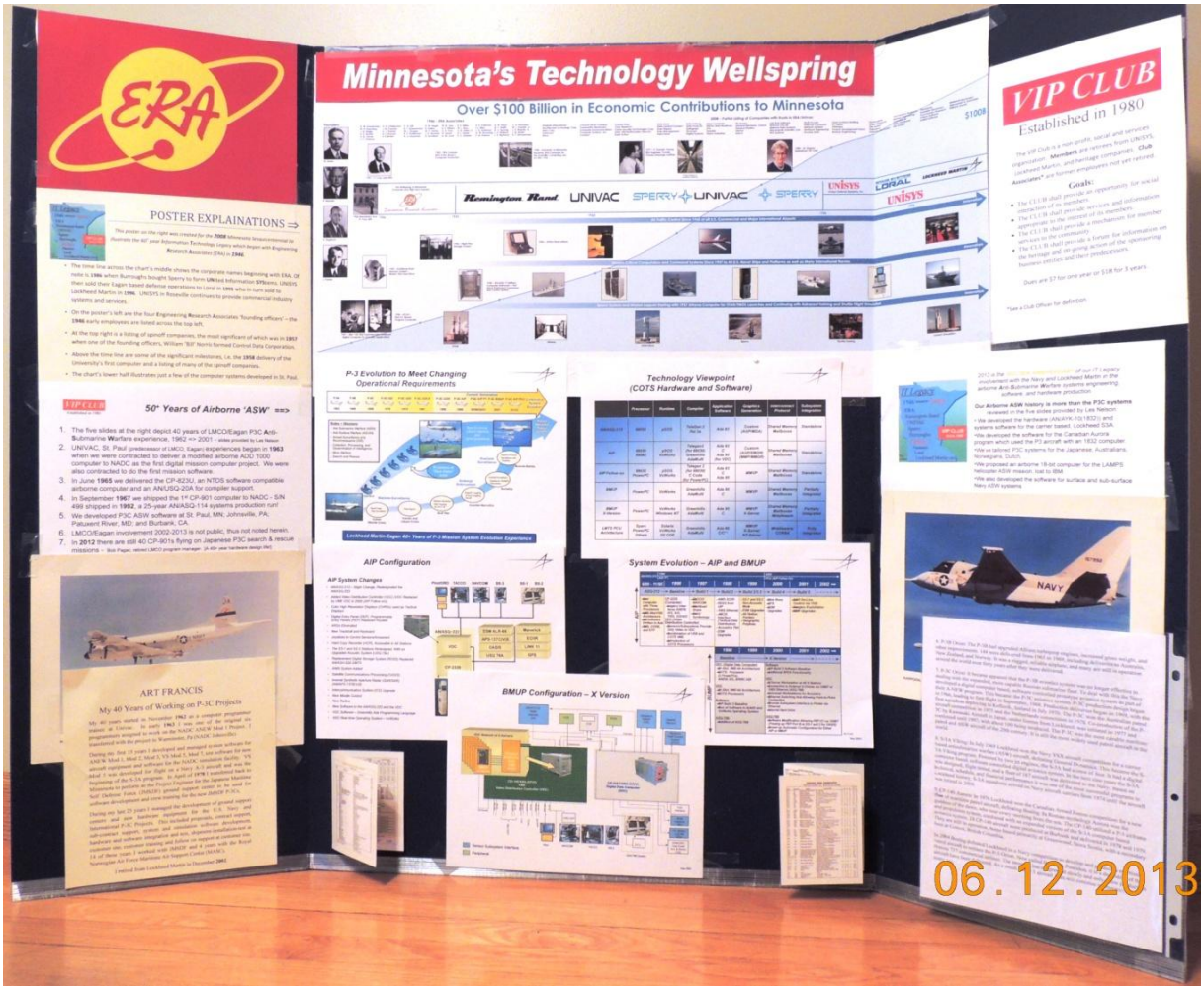


*2013 is the **GOLDEN ANNIVERSARY** of our IT Legacy involvement with the Navy and Lockheed Martin in the airborne **A**nti-**S**ubmarine **W**arfare systems engineering, software, and hardware production.*

Table of Contents

Introduction

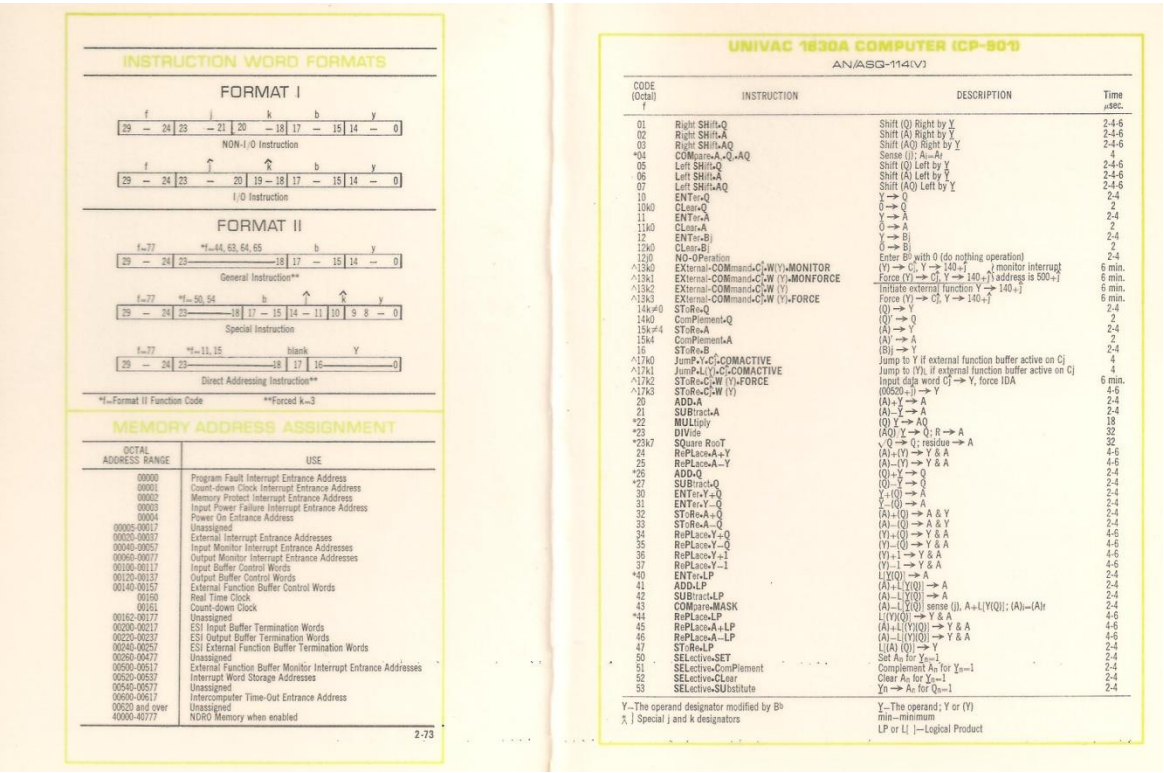
At the VIP Club's 2013 Picnic, we recognized 50 years of cooperation between UNIVAC/Sperry/UNISYS and Lockheed Martin in the development of an airborne Anti-Submarine Warfare (ASW) capability for the U.S. Navy. This capability has transitioned to Ocean Surveillance systems as the cold war Soviet threat lessened in the late 80s and early 90s. The picnic display snapshot below shows aspects of these 50 years as an integral part of our 65+ year Information Technology Legacy. This legacy began with Engineering Research Associates (ERA) in 1946 in St. Paul Minnesota – continues today at various non-Minnesota Lockheed Martin facilities. The following sections are details shown on the poster.



The Highlights of 50 Years by Lowell Benson

1. The five slides in the following section depict 40 years of LMCO/Eagan P3C **A**nti-**S**ubmarine **W**arfare experience, 1962 => 2001 - slides provided by Les Nelson.
2. UNIVAC, St. Paul [predecessor of LMCO, Eagan] experiences began in **1963** when we were contracted to deliver a modified airborne ADD 1000 computer to NADC as the first digital mission computer project. We were also contracted to do the first mission software.
3. In June **1965** we delivered the CP-823U, an NTDS software compatible airborne computer and an AN/USQ-20A for compiler support.
4. In September **1967** we shipped the 1st CP-901 computer to NADC - S/N 499 shipped in **1992**, a 25-year AN/ASQ-114 systems production run!
5. We developed P3C ASW software at St. Paul, MN; Johnsville, PA; Patuxent River, MD; and Burbank, CA.
6. LMCO/Eagan involvement 2002-2013 is not public, thus not noted herein.
7. In **2012** there are still 40 CP-901s flying on Japanese P3C search & rescue missions - Bob Pagac, retired LMCO program manager. [A 45+ year hardware design life!]

The CP-901 [UNIVAC Type 1830A] computer shared the basic Instruction Set Architecture as the Navy's shipboard AN/USQ-20B computer.



INSTRUCTION WORD FORMATS

FORMAT I

NON-I/O Instruction

I/O Instruction

FORMAT II

General Instruction**

Special Instruction

Direct Addressing Instruction**

*f—Format II Function Code **Forced k=3

MEMORY ADDRESS ASSIGNMENT

OCTAL ADDRESS RANGE	USE
00000	Program Fault Interrupt Entrance Address
00001	Count-down Clock Interrupt Entrance Address
00002	Memory Protect Interrupt Entrance Address
00003	Input Power Failure Interrupt Entrance Address
00004	Power On Entrance Address
00005-00017	Unassigned
00020-00037	External Interrupt Entrance Addresses
00040-00057	Input Monitor Interrupt Entrance Addresses
00060-00077	Output Monitor Interrupt Entrance Addresses
00100-00117	Input Buffer Control Words
00120-00137	Output Buffer Control Words
00140-00157	External Function Buffer Control Words
00160	Real Time Clock
00161	Count-down Clock
00162-00177	Unassigned
00200-00217	ESI Input Buffer Termination Words
00220-00237	ESI Output Buffer Termination Words
00240-00257	ESI External Function Buffer Termination Words
00260-00477	Unassigned
00500-00517	External Function Buffer Monitor Interrupt Entrance Addresses
00520-00537	Interrupt Word Storage Addresses
00540-00577	Unassigned
00600-00617	Intercomputer Time-Out Entrance Address
00620 and over	Unassigned
40000-40777	NORO Memory when enabled

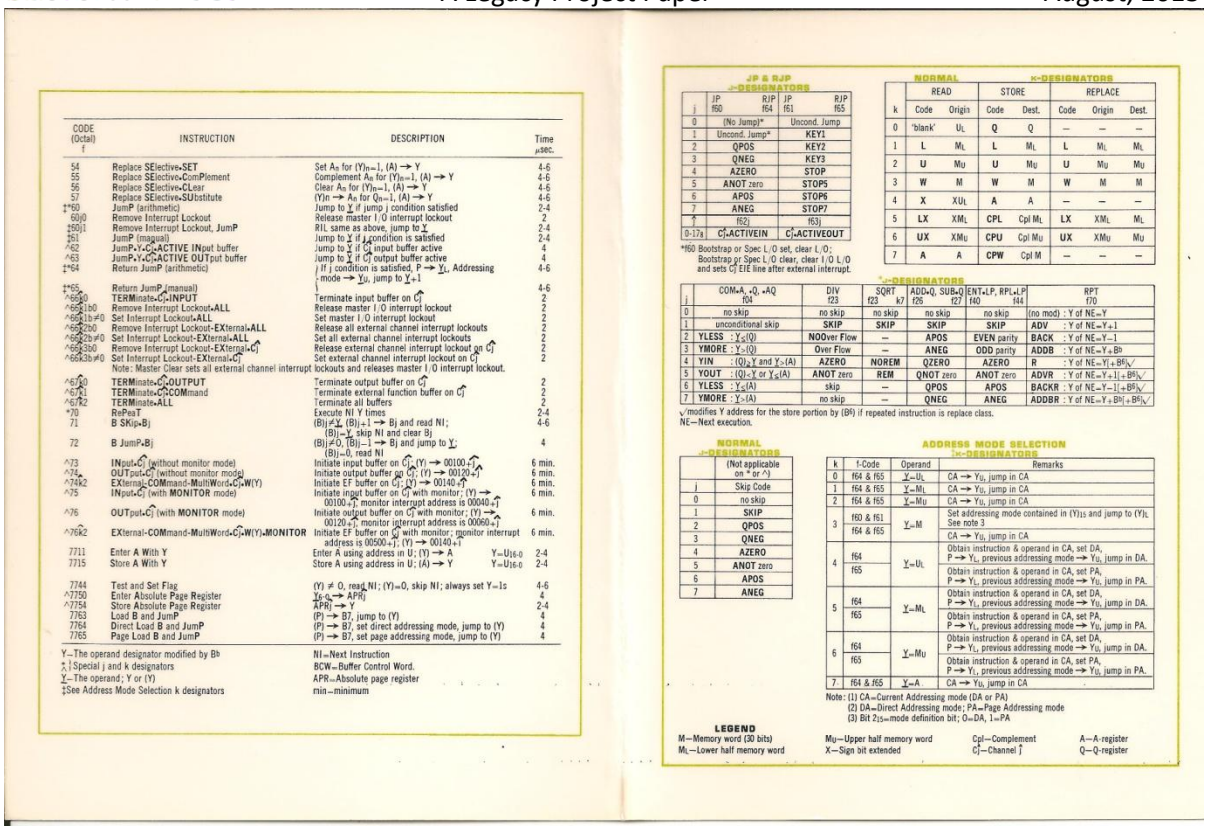
2-73

UNIVAC 1830A COMPUTER (CP-901)
AN/ASQ-114(V)

CODE (Octal) f	INSTRUCTION	DESCRIPTION	Time μsec.
01	Right SHift-Q	Shift (Q) Right by Y	2-4-6
02	Right SHift-A	Shift (A) Right by Y	2-4-6
03	Right SHift-AQ	Shift (AQ) Right by Y	2-4-6
*04	COMpare-A-Q-AQ	Sense (j); A_{15}=A_{17}	4
05	Left SHift-Q	Shift (Q) Left by Y	2-4-6
06	Left SHift-A	Shift (A) Left by Y	2-4-6
07	Left SHift-AQ	Shift (AQ) Left by Y	2-4-6
10	ENTer-Q	Y → Q	2-4
10k0	CLear-Q	0 → Q	2
11	ENTer-A	Y → A	2-4
11k0	CLear-A	0 → A	2
12	ENTer-Bj	Y → Bj	2-4
12k0	CLear-Bj	0 → Bj	2
12j0	NO-OPeration	Enter Bj with 0 (do nothing operation)	2-4
^13k0	EXternal-COMmand-Cj-W(Y)-MONITOR	(Y) → Cj, Y → [40+] (monitor interrupt	6 min.
^13k1	EXternal-COMmand-Cj-W (Y)-MONFORCE	Force (Y) → Cj, Y → [40+]) address is 500+]	6 min.
^13k2	EXternal-COMmand-Cj-W (Y)	Initiate external function Y → [40+]	6 min.
^13k3	EXternal-COMmand-Cj-W (Y)-FORCE	Force (Y) → Cj, Y → [40+]	6 min.
14k≠0	STore-Q	(Q) → Y	2-4
14k0	ComPlement-Q	(Q) → Q	2
15k≠4	STore-A	(A) → Y	2-4
15k4	ComPlement-A	(A) → A	2
16	STore-Bj	(Bj) → Y	2-4
^17k0	JumP-Y-Cj-COMACTIVE	Jump to Y if external function buffer active on Cj	4
^17k1	JumP-L(Y)-Cj-COMACTIVE	Jump to (Y), if external function buffer active on Cj	4
^17k2	STore-Cj-W (Y)-FORCE	Input data word Cj → Y, force IDA	6 min.
^17k3	STore-Cj-W (Y)	(00520+j) → Y	4-6
20	ADD-A	(A)+Y → A	2-4
21	SUBtract-A	(A)−Y → A	2-4
*22	MULtiply	(Q) Y → AQ	18
*23	DIVide	(AQ) Y → Q; R → A	32
*23k7	Square RooT	√ Q → Q; residue → A	32
24	RePLAce-A+Y	(A)+(Y) → Y & A	4-6
25	RePLAce-A−Y	(A)−(Y) → Y & A	4-6
*26	ADD-Q	(Q)+Y → Q	2-4
*27	SUBtract-Q	(Q)−Y → Q	2-4
30	ENTer-Y+Q	Y+(Q) → A	2-4
31	ENTer-Y−Q	Y−(Q) → A	2-4
32	STore-A+Q	(A)+(Q) → A & Y	2-4
33	STore-A−Q	(A)−(Q) → A & Y	2-4
34	RePLAce-Y+Q	(Y)+(Q) → Y & A	4-6
35	RePLAce-Y−Q	(Y)−(Q) → Y & A	4-6
36	RePLAce-Y+1	(Y)+1 → Y & A	4-6
37	RePLAce-Y−1	(Y)−1 → Y & A	4-6
*40	ENTer-LP	L(Y)(Q) → A	2-4
41	ADD-LP	(A)+L(Y)(Q) → A	2-4
42	SUBtract-LP	(A)−L(Y)(Q) → A	2-4
43	COMpare-MASK	(A)−L(Y)(Q) sense (j), A_{15}+L(Y)(Q)]; (A)=(A)r	2-4
*44	RePLAce-LP	L(Y)(Q) → Y & A	4-6
45	RePLAce-A+LP	(A)+L(Y)(Q) → Y & A	4-6
46	RePLAce-A−LP	(A)−L(Y)(Q) → Y & A	4-6
47	STore-LP	L(A) (Q)] → Y	2-4
50	SELective-SET	Set A_{17} for Y_{17}=1	2-4
51	SELective-ComPlement	Complement A_{17} for Y_{17}=1	2-4
52	SELective-CLear	Clear A_{17} for Y_{17}=1	2-4
53	SELective-SUbstitute	Y_{17} → A_{17} for Q_{17}=1	2-4

Y—The operand designator modified by Bj
x, j Special j and k designators

Y—The operand; Y or (Y)
min—minimum
LP or L( )—Logical Product



CODE (Octal) f	INSTRUCTION	DESCRIPTION	Time μsec.
54	Replace SElective-SET	Set A_n for $(Y)_{n-1}$, (A) → Y	4-6
55	Replace SElective-ComPlement	Complement A_n for $(Y)_{n-1}$, (A) → Y	4-6
56	Replace SElective-CLear	Clear A_n for $(Y)_{n-1}$, (A) → Y	4-6
57	Replace SElective-SUbstitute	$(Y)_n$ → A_n for Q_{n-1}, (A) → Y	4-6
†^60	JumP (arithmetic)	Jump to Y if jump j condition satisfied	2-4
60[0]	Remove Interrupt Lockout	Release master I/O interrupt lockout	2
‡60[1]	Remove Interrupt Lockout, JumP	RIL same as above, jump to Y	2-4
†61	JumP (magual)	Jump to Y if $\overline{j}$ condition is satisfied	2-4
^62	JumP-Y-C$\hat{j}$-ACTIVE INput buffer	Jump to Y if $C\hat{j}$ input buffer active	4
^63	JumP-Y-C$\hat{j}$-ACTIVE OUTput buffer	Jump to Y if $C\hat{j}$ output buffer active	4
‡†64	Return JumP (arithmetic)	If j condition is satisfied, P → Y_L, Addressing mode → Y_U, jump to Y+1	4-6
‡†65	Return JumP (manual)		4-6
^66k0	TERMinate-C$\hat{j}$-INPUT	Terminate input buffer on $C\hat{j}$	2
^66k1b0	Remove Interrupt Lockout-ALL	Release master I/O interrupt lockout	2
^66k1b≠0	Set Interrupt Lockout-ALL	Set master I/O interrupt lockout	2
^66k2b0	Remove Interrupt Lockout-EXternal-ALL	Release all external channel interrupt lockouts	2
^66k2b≠0	Set Interrupt Lockout-EXternal-ALL	Set all external channel interrupt lockouts	2
^66k3b0	Remove Interrupt Lockout-EXternal-C$\hat{j}$	Release external channel interrupt lockout on $C\hat{j}$	2
^66k3b≠0	Set Interrupt Lockout-EXternal-C$\hat{j}$	Set external channel interrupt lockout on $C\hat{j}$	2
	Note: Master Clear sets all external channel interrupt lockouts and releases master I/O interrupt lockout.		
^67k0	TERMinate-C$\hat{j}$-OUTPUT	Terminate output buffer on $C\hat{j}$	2
^67k1	TERMinate-C$\hat{j}$-COMmand	Terminate external function buffer on $C\hat{j}$	2
^67k2	TERMinate-ALL	Terminate all buffers	2
*70	RePeaT	Execute NI Y times	2-4
71	B SKip-Bj	(Bj)≠Y_L (Bj)+1 → Bj and read NI; (Bj)=Y_L skip NI and clear Bj	4-6
72	B JumP-Bj	(Bj)≠0, (Bj)−1 → Bj and jump to Y_U; (Bj)=0, read NI	4
^73	INput-C$\hat{j}$ (without monitor mode)	Initiate input buffer on $C\hat{j}$, (Y) → 00100-$\hat{j}$	6 min.
^74	OUTput-C$\hat{j}$ (without monitor mode)	Initiate output buffer on $C\hat{j}$; (Y) → 00120-$\hat{j}$	6 min.
^74k2	EXternal-COMmand-MultiWord-C$\hat{j}$-W(Y)	Initiate EF buffer on $C\hat{j}$; (Y) → 00140-$\hat{j}$	6 min.
^75	INput-C$\hat{j}$ (with MONITOR mode)	Initiate input buffer on $C\hat{j}$ with monitor; (Y) → 00100-$\hat{j}$, monitor interrupt address is 00040-$\hat{j}$	6 min.
^76	OUTput-C$\hat{j}$ (with MONITOR mode)	Initiate output buffer on $C\hat{j}$ with monitor; (Y) → 00120-$\hat{j}$, monitor isterrupt address is 00060-$\hat{j}$	6 min.
^76k2	EXternal-COMmand-MultiWord-C$\hat{j}$-W(Y)-MONITOR	Initiate EF buffer on $C\hat{j}$ with monitor; monitor interrupt address is 00500-$\hat{j}$, (Y) → 00140-$\hat{j}$+1	6 min.
7711	Enter A With Y	Enter A using address in U; (Y) → A $Y=U_{16-0}$	2-4
7715	Store A With Y	Store A using address in U; (A) → Y $Y=U_{16-0}$	2-4
7744	Test and Set Flag	(Y) ≠ 0, read NI; (Y)=0, skip NI; always set Y=1s	4-6
^7750	Enter Absolute Page Register	Y_{6-0} → APR	4
^7754	Store Absolute Page Register	APR → Y	2-4
7763	Load B and JumP	(P) → B7, jump to (Y)	4
7764	Direct Load B and JumP	(P) → B7, set direct addressing mode, jump to (Y)	4
7765	Page Load B and JumP	(P) → B7, set page addressing mode, jump to (Y)	4

Y—The operand designator modified by Bb
‡ | Special j and k designators
Y—The operand; Y or (Y)
‡See Address Mode Selection k designators

NI—Next Instruction
BCW—Buffer Control Word.
APR—Absolute page register
min—minimum

JP & RJP j-DESIGNATORS

j	JP f60	RJP f64	JP f61	RJP f65
0	(No Jump)*		Uncond. Jump	
1	Uncond. Jump*		KEY1	
2	QPOS		KEY2	
3	QNEG		KEY3	
4	AZERO		STOP	
5	ANOT zero		STOP5	
6	APOS		STOP6	
7	ANEG		STOP7	
↑	f62j		f63j	
0-17a	C$\hat{j}$-ACTIVEIN		C$\hat{j}$-ACTIVEOUT	

*f60 Bootstrap or Spec L/O set, clear L/O;
Bootstrap or Spec L/O clear, clear I/O L/O
and sets C$\hat{j}$ EIE line after external interrupt.

NORMAL k-DESIGNATORS

k	READ Code	READ Origin	STORE Code	STORE Dest.	REPLACE Code	REPLACE Origin	REPLACE Dest.
0	'blank'	U_L	Q	Q	—	—	—
1	L	M_L	L	M_L	L	M_L	M_L
2	U	M_U	U	M_U	U	M_U	M_U
3	W	M	W	M	W	M	M
4	X	XU[L]	A	A	—	—	—
5	LX	XM_L	CPL	Cpl M_L	LX	XM_L	M_L
6	UX	XM_U	CPU	Cpl M_U	UX	XM_U	M_U
7	A	A	CPW	Cpl M	—	—	—

***-DESIGNATORS**

j	COM-A-Q, +Q, +AQ f04	DIV f23	SQRT f23 k7	ADD-Q, SUB-Q f25 f27	ENT-LP, RPL+LP f40 f44	RPT f70
0	no skip	no skip	no skip	no skip	no skip	(no mod) : Y of NE→Y
1	unconditional skip	SKIP	SKIP	SKIP	SKIP	ADV : Y of NE→Y+1
2	YLESS : Y_L(Q)	NOOver Flow	—	APOS	EVEN parity	BACK : Y of NE→Y−1
3	YMORE : Y_L(Q)	Over Flow	—	ANEG	ODD parity	ADDB : Y of NE→Y+B[k]
4	YIN : (Q)∧Y and Y_L(A)	AZERO	NOREM	QZERO	AZERO	R : Y of NE→Y[L]+B[k]√
5	YOUT : (Q)∧Y or Y_L(A)	ANOT zero	REM	QNOT zero	ANOT zero	ADVR : Y of NE→Y+1[L]+B[k]√
6	YLESS : Y_L(A)	—	—	APOS	APOS	BACKR : Y of NE→Y−1[L]+B[k]√
7	YMORE : Y_L(A)	no skip	—	QNEG	ANEG	ADDBR : Y of NE→Y+B[k]+B[k]√

√modifies Y address for the store portion by (B[k]) if repeated instruction is replace class.
NE—Next execution.

NORMAL j-DESIGNATORS

j	(Not applicable on * or ^)
0	Skip Code
1	no skip
2	SKIP
3	QPOS
4	QNEG
5	AZERO
6	ANOT zero
7	APOS
	ANEG

ADDRESS MODE SELECTION k-DESIGNATORS

k	f-Code	Operand	Remarks
0	f64 & f65	X_{-U_L}	CA → Y_U, jump in CA
1	f64 & f65	X_{-M_L}	CA → Y_U, jump in CA
2	f64 & f65	X_{-M_U}	CA → Y_U, jump in CA
3	f60 & f61	Y_{-M}	Set addressing mode contained in $(Y)_{15}$ and jump to $(Y)_L$ See note 3
	f64 & f65		CA → Y_U, jump in CA
4	f64	X_{-U_L}	Obtain instruction & operand in CA, set DA, P → Y_L, previous addressing mode → Y_U, jump in DA.
	f65		Obtain instruction & operand in CA, set PA, P → Y_L, previous addressing mode → Y_U, jump in PA.
5	f64	Y_{-M_L}	Obtain instruction & operand in CA, set DA, P → Y_L, previous addressing mode → Y_U, jump in DA.
	f65		Obtain instruction & operand in CA, set PA, P → Y_L, previous addressing mode → Y_U, jump in PA.
6	f64	X_{-M_U}	Obtain instruction & operand in CA, set DA, P → Y_L, previous addressing mode → Y_U, jump in DA.
	f65		Obtain instruction & operand in CA, set PA, P → Y_L, previous addressing mode → Y_U, jump in PA.
7	f64 & f65	X_{-A}	CA → Y_U, jump in CA

Note: (1) CA—Current Addressing mode (DA or PA)
(2) DA—Direct Addressing mode; PA—Page Addressing mode
(3) Bit Z_{15}—mode definition bit; 0—DA, 1—PA

LEGEND
M—Memory word (30 bits)
M_L—Lower half memory word
M_U—Upper half memory word
X—Sign bit extended
Cpl—Complement
C$\hat{j}$—Channel $\hat{j}$
A—A-register
Q—Q-register

A 40 Year Programming Career by Art Francis

My 40 years started in November **1962** as a computer programmer trainee at Univac. In early **1963** I was one of the original six programmers assigned to work on the NADC ANEW Mod 1 Project. I transferred with the project to Warminster, Pa (Naval Air Development Center, Johnsville).

During my first 15 years I developed and managed system software for ANEW Mod 1, Mod 2, Mod 3, VS Mod 5, Mod 7, test software for new aircraft equipment and software for the NADC simulation facility. VS Mod 5 was developed for flight on a Navy A-3 aircraft and was the beginning of the S-3A program. In April of **1978** I transferred back to Minnesota to perform as the Project Engineer for the Japanese Maritime Self Defense Force (JMSDF) ground support center to be used for software development and crew training for the new JMSDF P-3Cs.

Photo taken by LABenson at the VIP Club's 2013 Grand Reunion Picnic.

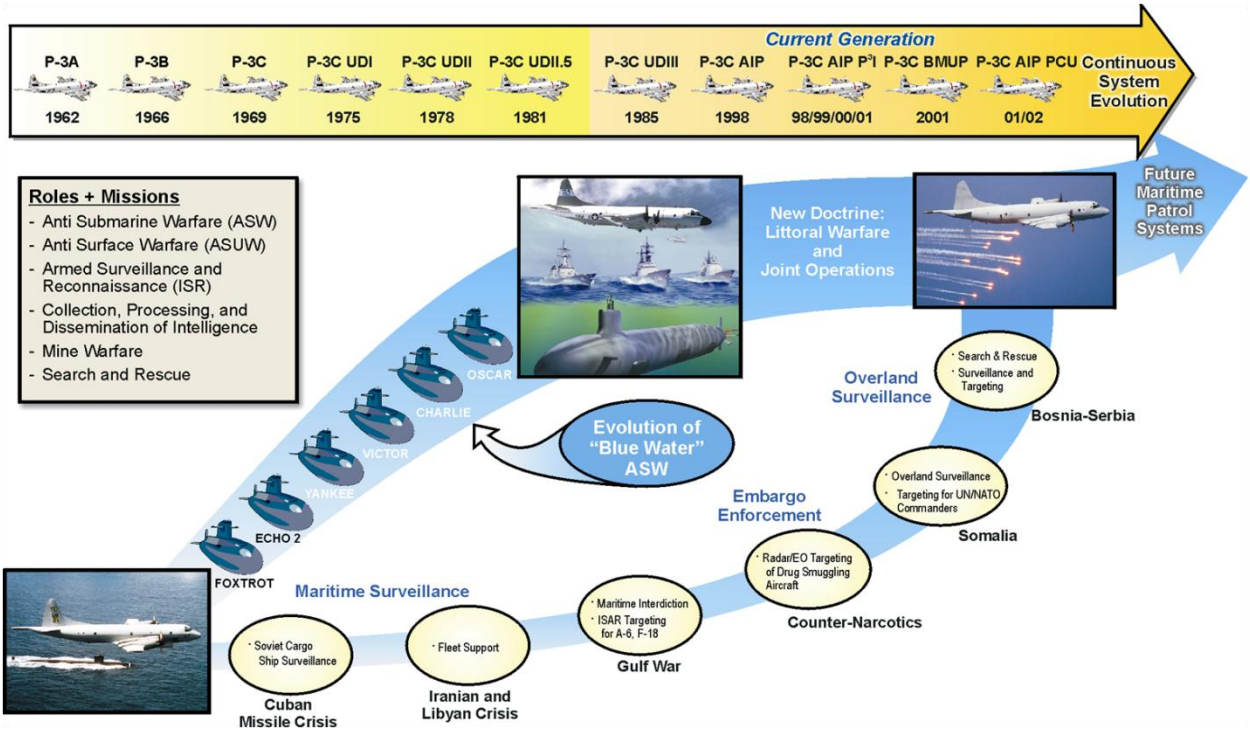
During my last 25 years I managed the development of ground support centers and new hardware equipment for the U.S. Navy and International P-3C Projects. This included proposals, contract

support, sub-contract support, system and simulation software development, hardware and software integration and test, shipment-installation-test at customer site, customer training and follow on support at customer site. 14 of these years I worked with JMSDF and 4 years with the Royal Norwegian Air Force Maritime Air Support Center (MASC).

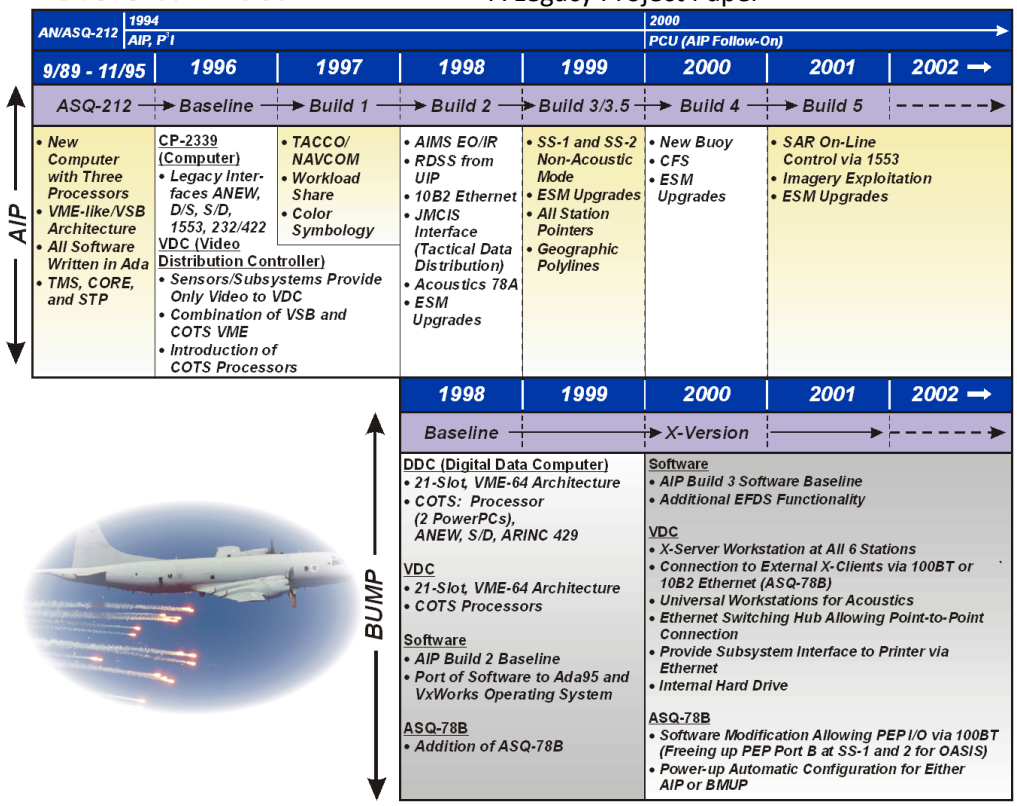
I retired from Lockheed Martin in December **2002**.

Evolution of Systems by Les Nelson

These slides were developed by Les in 2001 to show the Lockheed system evolution.



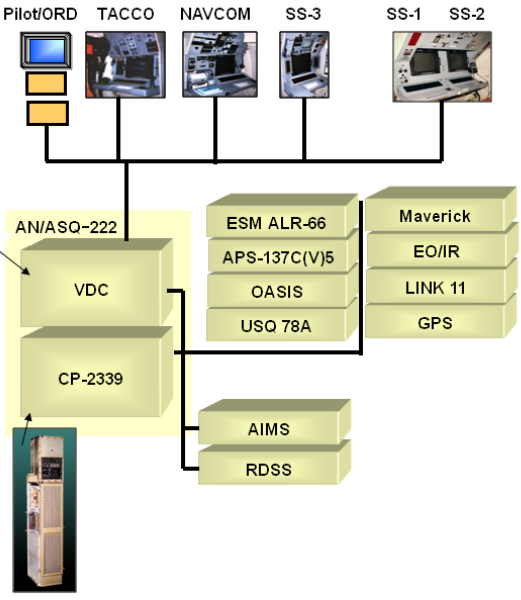
The hardware and software evolution charts begin in 1994 as the original CP-901 mission computer of the AN/ASQ-114 system was being replaced with newer embedded Commercial-Off-The-Shelf (COTS)CP-2044 hardware of the AN/ASQ-212 system.



AIP Configuration

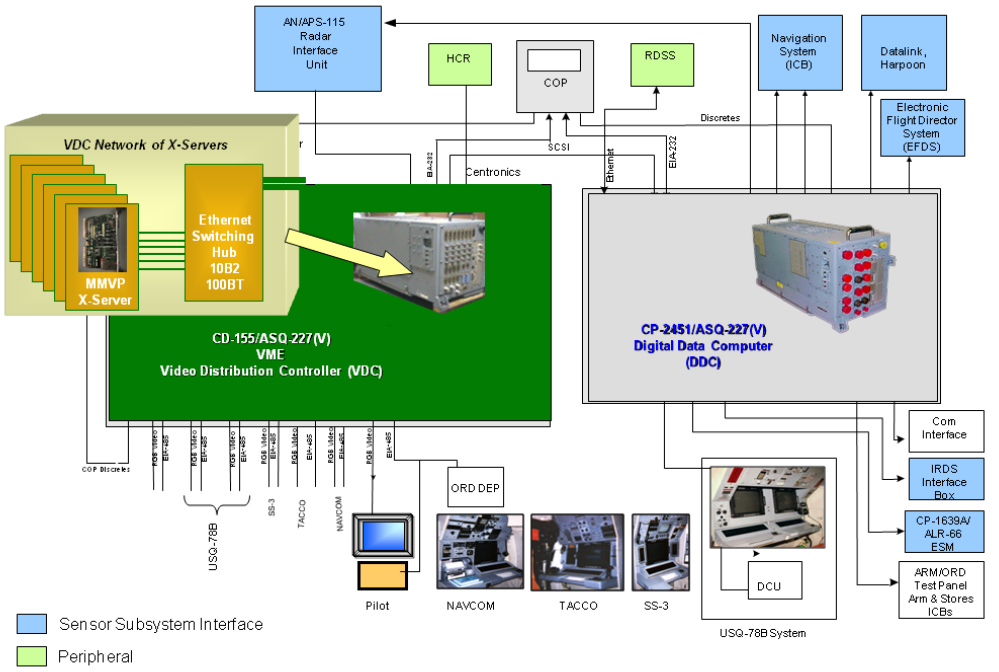
AIP System Changes

- AN/ASQ-212 – Slight Change, Re-designated the AN/ASQ-222
- Added Video Distribution Controller (VDC) (VDC Replaced by VME VDC in 2000 (AIP Follow-on))
- Color High Resolution Displays (CHRDs) used as Tactical Displays
- Digital Entry Panel (DEP), Programmable Entry Panels (PEP) Replaced Keysets
- AROs Eliminated
- New Trackball and Keyboard
- Joysticks to Control Sensors/Armament
- Hard Copy Recorder (HCR), Accessible to All Stations
- The SS-1 and SS-2 Stations Redesigned, With an Upgraded Acoustic System (USQ-78A)
- Replacement Digital Storage System (RDSS) Replaced AN/ASH-33A DMTS
- AIMS System Added
- Satellite Communications Processing (OASIS)
- Inverse Synthetic Aperture Radar (ISAR/SAR) (AN/APS-137B(V)5)
- Intercommunication System (ICS) Upgrade
- New Missile Control
- New Radios
- New Software to the AN/ASQ-222 and the VDC
- VDC Software – Greenhills Ada Programming Language
- VDC Real-time Operating System – VxWorks



Nov 2001

BMUP Configuration – X Version



Nov 2001

Technology Viewpoint (COTS Hardware and Software)

	Processor	Runtime	Compiler	Application Software	Graphics Generation	Interconnect Protocol	Subsystem Integration
AN/ASQ-212	68030	pSOS	TeleGen 2 Rel 2a	Ada 83	Custom (AGP/MDA)	Shared Memory Mailboxes	Standalone
AIP	68030 68060	pSOS VxWorks	Telegen2 (for 68030) Greenhills AdaMulti	Ada 83 C Ada 95 (for VDC)	Custom (AGP/EMDR) (MMP/MMDR)	Shared Memory Mailboxes	Standalone
AIP Follow-on	68030 PowerPC	pSOS VxWorks	Telegen 2 (for 68030) C Code (for PowerPC)	Ada 83 C Ada 95	MMVP	Shared Memory Mailboxes	Standalone
BMUP	PowerPC	VxWorks	Greenhills AdaMulti	Ada 95 C	MMVP	Shared Memory Mailboxes	Partially Integrated
BMUP X-Version	PowerPC	VxWorks Windows NT	Greenhills AdaMulti	Ada 95 C	MMVP X-Server	Shared Memory Mailboxes Middleware	Partially Integrated
LMTS PCU Architecture	Sparc PowerPC Others	Solaris VxWorks Dll COE	Greenhills AdaMulti	Ada 95 C/C++	MMVP X-Server NT-Server	Middleware/ CORBA	Fully Integrated

Nov 2001

Golden Anniversary by Lowell Benson

Our Airborne ASW history is more than the P3C systems reviewed in the five slides provided by Les Nelson:

- We developed the hardware (AN/AYK-10(1832)) and systems software for the carrier based, Lockheed S3A.
- We developed the software for the Canadian Aurora program which used the P3 aircraft with an 1832 computer.
- We've tailored P3C systems for the Japanese, Australians, Norwegians, Dutch, …
- We proposed an airborne 18-bit computer for the LAMPS helicopter ASW mission, lost to IBM.

Editor's notes:

1. The AN/AYK-10 computer shared the same 32-bit Instruction Set Architecture as the Navy's 3rd generation computer, the AN/UYK-7.
2. The S-3A was upgraded to an S3-B in the late 80s with the addition of Harpoon air-to-surface missile launch capability under a contract to then Sperry. At that time, the AN/AYK-10 mission computer memory was also upgraded to a semiconductor based memory designed in St. Paul. The memory manufacturing was done in Winnipeg in cooperation with the Canadian CP-140 memory upgrade.

3. Tom Wilson has provided insight regarding our AYK-23 digital Computer Processor Memory Unit (CPMU), the last S-3B Viking squadron was decommissioned in 2009, but in June 2010, several S3B Vikings were re-activated to patrol the Pacific Missile Test Center's range areas off the coast of California. From Ed Pogorzelec.

Lockheed Maritime Patrol Aircraft by Sherm Mullin

More by accident than plan, Lockheed abruptly entered the maritime patrol aircraft business in 1938 when the British government, seeing World War II on the horizon, sent a commission to the U.S to immediately buy large numbers of aircraft for the Royal Air Force (RAF). They purchased a military derivative of the Model 14 Super Electra commercial airliner, which they named the Hudson, after British explorer Henry Hudson.

1. Hudson: Although often called the Hudson bomber, the primary use of the Hudson by the Royal Air Force was maritime patrol and antisubmarine warfare (ASW), conducted intensely against the German submarine force after WW II started in September, 1939. This became known as the battle of the Atlantic, which was very intense during the early years of the war when allied shipping losses caused by German U boat attacks were very severe. The Hudson program transformed Lockheed

into a large company in 1939. Peak Hudson production was 1,127 in 1941. 2,941 Hudsons were produced before the line was shut down in 1943. Other operators included Australia, New Zealand and Canada, all of whom are still operating Lockheed maritime patrol aircraft seventy years later, as this is written.

2. PV-1 Ventura: The Ventura was a derivative of the Lockheed Model 18 Lodestar military transport. The initial customer was the Royal Air Force, wanting a more capable aircraft than the Hudson. First delivered in 1941 it went through several major design upgrades and was later ordered in large numbers by the U. S. Navy, with 1,600 delivered as maritime patrol aircraft from 1942 to 1944. In early 1942 a decision had been made that land-based airborne ASW aircraft would be operated by the Navy, not the Army Air Force. This policy decision obviously had a major impact on Lockheed, lasting for the rest of the 20th century.

3. PV-2 Harpoon: Working with the U. S. Navy the Harpoon was a derivative of the Ventura, designed for maritime patrol missions. It had bigger wings, increased fuel, and heavier payload capacity. A total of 3,038 Venturas and Harpoons of several different configurations were delivered from 1941 to 1945, when the line was shut down.

4. P-2 Neptune: The P-2 was the first Lockheed aircraft designed from day one for maritime patrol and antisubmarine warfare. It was a twin piston engine long range aircraft which went through seven major configuration updates, incorporating the latest ASW electronics systems. The development contract from the Navy was received in February 1943, with first flight achieved on May17, 1945. It was in production from 1946 to 1962. 1051 were produced, which included a large number of international sales. An additional 131 Neptunes were built under Lockheed license by Kawasaki Aircraft in Japan, delivered from 1959 to 1979.

5. P-3A Orion: The P-3A was a derivative of the Lockheed Model 188 Electra four-engine turboprop commercial airliner. Selected by the Navy to replace the P-2, the development contract was awarded in May, 1958. The first Navy squadron became operational in 1962, and played a significant role in the Cuban missile crisis later that year. 157 were delivered from 1961 to 1965.

6. P-3B Orion: The P-3B had upgraded Allison turboprop engines, increased gross weight, and other improvements. 144 were delivered from 1965 to 1969, including deliveries to Australia, New Zealand, and Norway. It was a rugged, reliable airplane, and many are still in operation around the world over forty years after they were delivered.

7. P-3C Orion: It became apparent that the P-3B avionics system was no longer effective in dealing with the expanded, more capable Russian submarine fleet. To deal with this the Navy developed a digital computer based, software controlled prototype avionics system as part of their A-NEW program. This became the P-3C avionics system. P-3C production design began in 1966, leading to first flight in September, 1968. Production deliveries began in 1969, with the first squadron deploying to Keflavik, Iceland in July 1970. The P-3C won the Australian patrol aircraft competition in 1975 and the Netherlands competition in 1978. Co-production of the P-3C by Kawasaki Aircraft in

Japan, under license from Lockheed, was initiated in 1977 and continued until 1997, with about 100 being produced. The P-3C was the most capable maritime patrol and ASW aircraft of the 20th century. It is still the most widely used patrol aircraft in the world.

8. S-3A Viking: In July 1969 Lockheed won the Navy VSX aircraft competition for a carrier based antisubmarine warfare (ASW) aircraft, defeating General Dynamics. This became the S-3A Viking program. Powered by two jet engines, the S-3A had a crew of four. It had a digital computer based, software controlled digital avionics system. In the next nine years the S-3A was designed, flight tested, and a fleet of 187 aircraft was delivered to the Navy. Based on technical, schedule, and financial performance it was one of the most successful programs in Lockheed history. S-3A squadrons served on Navy aircraft carriers from 1974 until the aircraft was retired in 2009.

9. CP-140 Aurora: In 1976 Lockheed won the Canadian Armed Forces competition for a new fleet of maritime patrol aircraft, defeating Boeing. In Roman mythology Aurora was the goddess of the dawn, who rose every morning from the sea. The CP-140 utilized a P-3 airframe and propulsion system, combined with an expanded version of the S-3A computer based avionics system. 18 CP-140 aircraft were produced at Burbank and delivered in 1978 and 1979. They are still in operation; home based primarily at Greenwood, Nova Scotia, with a secondary base at Comox, British Columbia.

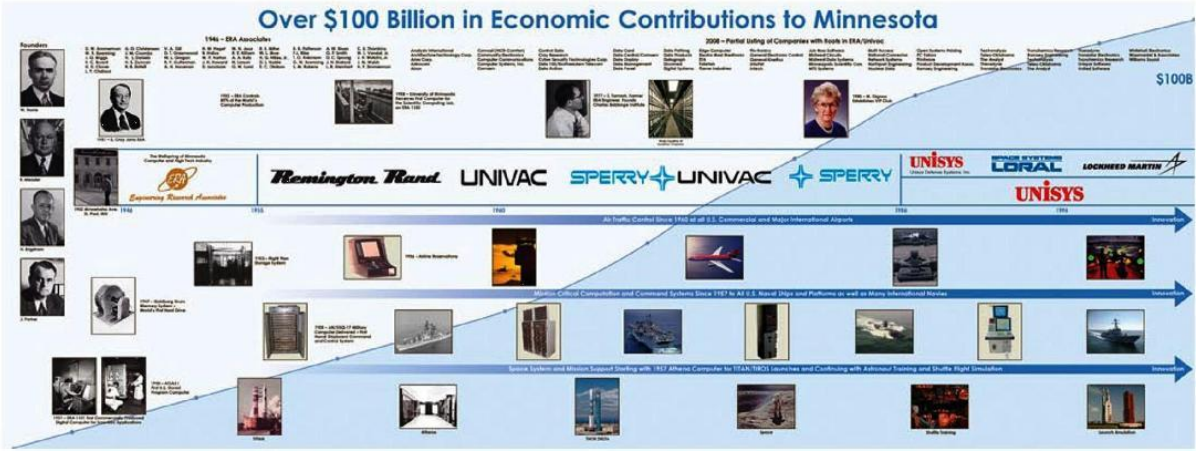
In 2004 Boeing defeated Lockheed in a Navy competition to develop and produce a maritime patrol aircraft to replace the P-3 Orion. Now called the P-8A Poseidon, it is a derivative of the Boeing 737 commercial airliner. The program has progressed slowly and only a few production aircraft have been delivered. As a result, the P-3 aircraft fleet will continue in operation for many years.

IT Legacy Overview

The large poster at the top center of our display board [see next page image] was created for the **2008** Minnesota Sesquicentennial to illustrate the 60^{+} year **I**nformation **T**echnology Legacy which began with **E**ngineering **R**esearch **A**ssociates (ERA) in **1946**.

- The time line across the chart's middle shows the corporate names beginning with ERA. Of note is **1986** when Burroughs bought Sperry to form **UN**ited **I**nformation **SYS**tems. UNISYS then sold their Eagan based defense operations to Loral in **1995** who in turn sold to Lockheed Martin in **1996**. UNISYS in Roseville continues to provide commercial industry systems and services.
- On the poster's left are the four **E**ngineering **R**esearch **A**ssociates 'founding officers' – the **1946** early employees are listed across the top left.
- At the top right is a listing of spinoff companies, the most significant of which was in **1957** when one of the founding officers, William 'Bill' Norris formed Control Data Corporation.
- Above the time line are some of the significant milestones, i.e. the **1958** delivery of the University's first computer and a listing of many of the spinoff companies.

- The chart's lower half illustrates just a few of the computer systems developed in St. Paul.



The Future

Parts of this continuing ASW history will soon be on active display at the Dakota County Historical Society's Lawshe Memorial Museum in South St. Paul, MN. Shown at the right are Bob Pagac, retired program manager; Les Nelson, retired systems engineer; CP-2044, retired P3C computer; Pat Myhre, retired CP-901 programmer; and Harvey Taipale, VIP Club Treasurer.

Attachments

Although not shown on the display at the picnic, it is appropriate to include the following web site items as part of this ASW evolution history.

The Beginning by Bob Blixt [deceased]

In 1962 the Univac marketing folks located a promising Naval Air program at the Naval Air Development Center at Johnsville, PA, called ANEW. {Editor's note: ANEW is not an acronym, it is simply 'a new' approach to ASW, i.e. using a digital versus an analog computer.} The objective of this program was to greatly improve the Anti-Submarine Warfare (ASW) capabilities of the P-3 aircraft. The then aircraft had an analog system that needed to be updated to the digital world. With our NTDS work and proven capability in building military digital computers, we were a good fit to help them with their program.

Our first attempt was the use of a "left over" computer from the Titan program called ADD (Advance Digital Development) and a display system to show the possibilities of a digital airborne ASW system. The programming of the ADD computer proved to be very difficult so it was abandoned

early in the game. In 1963 we sold the development of a computer [CP-823U] for the ANEW test aircraft. This aircraft made flights to St. Paul so our programmers could add programs and make changes. Some test flights were made from here, one to Lake Superior to test dropping sono-buoys with the digital system. The system continued development and the flight testing was set up at the Patuxent Naval Air Testing Center (Pax river) in Maryland. These tests required some of our programmers to go on these test flights. Some of our guys came back very airsick after going through some of the flight maneuvers of the test. We decided to recognize their "beyond the call of duty" effort and created the "Flying Programmer" award for them. It was this dedicated, creative hard work by these programmers that made this system go. The system did go. After many months of hardware and software problems, a sea test was set. An American submarine was used as the target and the ANEW system with our computer and software tracked it. The next step was a pre-production system. In 1966 we received our first contract for the CP-901 computer. I was given the job to go to Washington and pick it up. Programming for the new computer was also our job. The system requirements were set by the Naval Air Development Center so a Univac programming office was set up at Johnsville, PA [Westminster.] Programming was also done in St. Paul. Production required a new interface for us to work with, the Lockheed company in Burbank, CA. I believe we were the first to bring the new digital world to Lockheed. We had several meetings with their management to explain the ANEW system and to talk about planning for it. After many months of software and hardware development the system was coming together: software at Johnsville, hardware and software in St. Paul, the aircraft and other system components in Burbank. It was a thrill for me to go to Burbank and walk through the first P-3C on the production line after all the struggles we went through to get to this point. Our first quantity production contract for the CP-901 computer was received in 1968. The P-3C went on for many years with many updates.

From 24 to 30 bits by Marwood Clement [deceased]

"What was ANEW Mod 2?" Marwood Clement replied in 2010: "You're asking a lot of someone who can barely remember what he did yesterday! The very first flight tests on the P3 used the Air Force missile computer, [Ed note: *Type 1020, CP/754*,] which was a 'dog' to program - we "extrapolated" from those confusing results to how good it was going to be. I always considered that my contribution was to suggest that we use the identical instruction repertoire as on the Q20 shipboard computer. That stopped a lot of debates at Johnsville and among our own engineers and didn't help IBM." *Marwood Clement*

Can you implement this? by Ned Hunter

After much "push and pull," my wife finally got me in the mood to clean the basement. The first item I came across was the box of personal effects that all people take with them when they leave the company. Plowing through the box, I came across an old YP-3C Specification for Display Software that started to bring back old memories. It took me back to a day in the early 60s when Dan Brophy came to me with something scribbled on an 8 1/2 x 11 piece of paper. He said it was a navigation program that he wanted implemented in a prototype computer that Bob Blixt and crew were developing. The purpose of the whole exercise was to demonstrate that a digital computer could replace [at least in part] the current analog computers. To do this, the plan was to receive data from

the P-3 navigation system and compute the airplane's position and track. I don't think anyone outside of Dan thought that it had a chance of working, especially management, because they gave the task to me. I had very little experience and certainly wasn't the sharpest blade in the drawer! With a meager beginning, Dan somehow parlayed this small contract with NADC into a modest contract for demonstration software to be implemented in an airborne computer aboard the P-3. Hence, MOD 1 was launched and with it was launched an era of excellence that apparently is still going on with many spin-offs. You could fill an auditorium with the people who contributed to the success of this program, but I still remember the day that Dan approached me with a piece of paper and asked, "Can you implement this?"

Well, back to cleaning the basement- Contributed by Ned Hunter

Working with Lockheed by Jim Rapinac

In 1963, Univac Defense Systems Division designed, developed and delivered a new airborne computer, CP-823U [Univac 1830] to the Naval Air Development Center, Warminster, PA, for U.S. Navy's ANEW program, an advanced airborne digital avionics system for anti submarine warfare. The CP-823U design was based on the instruction set of the USQ-20B and was also software compatible. Future production versions were assigned a USN nomenclature of CP-901.

In 1965, Univac was selected as the contractor to supply CP-901 computers to the US Navy for the P-3C program, a digital avionics upgrade for new land based Anti Submarine Warfare (ASW) aircraft. Lockheed California Aircraft Company, Burbank, CA, also known as CALAC, was the principle contractor for the P-3C, and Univac and other suppliers were called associate contractors. Univac CP-901 computers and other sub-systems were contracted by the US Navy and shipped to CALAC as government furnished equipment (GFE). The Univac field office at Naval Air Development Center (NADC), Warminster, PA, developed the P-3C operational programs which were also GFE'd to CALAC. Over 40 programmers worked on site at NADC and Univac continued work on various projects until NADC was closed in the late 1980's. Jim Rapinac's high school friend's father, C.J. Henkel, had been chief engineer at CALAC but was now retired. He introduced Mr. Rapinac to several CALAC executives including George Papen, P-3C chief engineer, and Bert O'Laughlin, VP of Marketing. We had open access to Don Wilder, President of CALAC, and his successors, Fred Lashley and Fred Jacques. These high level contacts provided Univac marketing and technical managers direct access to the CALAC P-3C program office. CALAC was then an airframe company with little or no computer or software expertise. We convinced them that to sell off P-3C aircraft to the US Navy they had to have a system test program. George Papen finally saw the light and bought the idea. The P-3C system test software was one of Univac's largest software development programs at that time, 1968. More importantly, CALAC began to rely on Univac for software development and support! The open and honest management style of Univac personnel combined with proven on time and on target performance forged a new and mutually beneficial relationship with CALAC for the P-3C program and future programs. Over 285 new P-3C aircraft were bought under the original program and several upgrade programs have extended the life of the P-3C, the first digital airborne anti-submarine warfare system.

In 1967 the U.S. Navy announced a new program, VS-X, a replacement for the Grumman S-2 carrier based ASW aircraft. Unlike the P-3C program, the VS-X would be a total package procurement with a single prime contractor. Grumman, McDonnell, Douglas, GD Convair, and CALAC were the initial competitors for a Concept Definition Phase Competition between 2 prime contractors followed by a down select to a single prime contractor. The 5 bidders all contacted Univac DSD since at that time DSD had the only technical expertise in airborne ASW digital systems. Mr. Rapinac was assigned as VS-X marketing manager. We met with all 5 bidders several times over a period of 6 months. Our strategy was to select and team with one company. In 1967 Grumman and McDonnell Aircraft were the only bidders currently making carrier based jet aircraft. Douglas and GD Convair made carrier based propeller aircraft during World War II and CALAC had never designed or built carrier based war planes. Grumman decided to pursue the F-4 replacement, VF-X, the F-14 Tomcat, which had planned quantities of over 1000 aircraft versus the VS-X by of 183 planes. They informally announced their no-bid decision, Grumman had been our first choice for teaming and now we decided that the second best choice was McDonnell Aircraft. Then, McDonnell announced a merged with Douglas. The two VS-X bidding teams, one in St. Louis and the other in Long Beach, CA, were merged but frictions developed. We were within weeks of finalizing a teaming agreement with McDonnell Douglas when negotiations broke off. We decided to team with Lockheed Aircraft. The CALAC VS-X team included Fred Jacques, Program Director ;Dick Heppe, Chief Engineer; Wally Weber, Marketing Manager; and a new face, Sherm Mullen - who was brought to Burbank from Lockheed Electronics, Plainfield, NJ, to develop a technical group for digital computers, software and systems. Mullen later became President of the Lockheed Skunk Works and was responsible for the F-117 and F-22 fighter programs. After numerous private off-site meetings at local Burbank restaurants, Univac DSD and CALAC signed an exclusive VS-X teaming agreement. Univac would be responsible for the computer and all operational programs and systems software. As part of the teaming agreement, Univac agreed to locate a technical team in Burbank, housed in Lockheed facilities.

In 1967, the U.S. Navy awarded 12 month Concept Definition Phase contracts to CALAC and GD Convair. It was no contest. CALAC won the VS-X development and production contract for 183 aircraft and support systems in 1968. The Univac portion of the initial contracts exceeded $200 million and was the largest single award in the history of the division (at that time.) Each 1832 airborne computer that was installed in S-3A aircraft had an initial price of $1 million! The names of CALAC and Univac became synonymous with success! As part of the Univac contract with CALAC for the S-3A program, DSD established a site in Valencia, California, near the CALAC Rye Canyon Facility. Over 40 programmers and systems engineers were relocated from St. Paul and Warminster, PA to staff the new site. Univac DSD people directly involved in the VS-X program were Forrest Crowe, VP & General Manager, Dewaine Osman, VP, Marketing, Forrest Lowe, Marketing Director, Avionics Systems, Arnie Hendrickson, Bob Blixt, and Dan Brophy, DSD Avionics and Aerospace Engineering and Jim Rapinac. There were also many other contributors in other functional organizations. Univac technical, management, and marketing personnel had CALAC contractor badges that allowed open access to CALAC buildings at the Burbank airport. Access to CALAC buildings was shown on our

contractor badges. The S-3A program became one of the most successful programs in U.S. Navy history. The program was completed on schedule, within target costs and was very, very profitable to both companies. Today, over 25 years after the initial contract award, S-3B aircraft, upgraded versions of the S-3A, are still fully operational.

In 1971, Jim Rapinac was named as General Manager, Sperry Univac, DSD, Salt Lake City, a division that supplied drone control systems and wide band data links. While in Salt Lake City, the business relationships with CALAC expanded to include the Skunk Works. We worked with Kelly Johnson and, later, his successors, Ben Rich and Sherm Mullen. The Salt Lake City group became a primary supplier of data links for the U2, SR-71 and other covert aircraft. Our long term management relationships with CALAC combined with a consistent record of or performance continued to pay dividends and was mutually beneficial and profitable to both companies. The current Lockheed Martin facility in Eagan has a long, successful and storied history in the global defense and aerospace industry and has survived numerous corporate changes and names including Engineering Research Associates (ERA), Remington Rand Univac (RRU), Univac Defense Systems Division, Sperry Univac Defense Products Group, Unisys, PARAMAX, Loral, and finally, Lockheed Martin MS2. Many current LM employees along with retired Univac DSD personnel, including me, owe our career successes, whatever they may be or have been, to the S-3A program and our association with CALAC. For some, it was their life's work! I know that I speak for all retirees of Sperry Univac Defense Systems Division when I say that nothing could be more appropriate or fitting than to have the name of Lockheed Martin on Plant 8 in Eagan, MN. [Jim Rapinac]

A Sub-hunter flight by Lowell Benson

In 1967 I was working checkout and test of the first CP-901 computers in Plant 1. The Navy flew a P3C into Wold Chamberlin Field - Jack Anderson [Field Service engineer] and I got on board with the CP-901 S/N 2 then flew to the Naval Air Development Center (NADC) at Johnsville, PA for the first customer delivery. Jack and I installed the CP-901 into their computer center for ASW software development. 15 years later, I smiled while watching the P3C in the 'Hunt for Red October' movie. I'd flown in a sub-hunter plane.

CP-823 (Type 1830)

This unit was to be the first flying 30-bit machine, developed for the Naval Air Development Center at Johnsville, PA. This unit is now in the hands of Todd J. Thomas after being in storage for almost 40 years. Mr. Thomas' photo of the various units is shown on the next page.

The preliminary Anti-Submarine Warfare (ASW) software development started with this unit. Pete Olson was one of the logic designers, George Kydd worked on the I/O units, Ray Bowar did some of the memory design, M. R. Clements was the marketing manager. This unit used some of the same integrated circuit flat packs as were developed for the 1824 computer. To minimize development costs, some of the logic card types used in the control console and ground support unit were copied from the CP-667.

CP-823/U SERIAL A1 COMPUTING SYSTEM, A-NEW MOD 3 (UNIVAC 1830). FROM LEFT TO RIGHT: 4 AIRBORNE I/O UNITS (SERIAL A1-A4), GROUND I/O, MEMORY, PROCESSOR, AIRBORNE POWER SUPPLY, CONTROL CONSOLE.

CP-901 - Univac Type #1830A

A design team led by supervisor, Ken Oehlers, began development of the CP-901 (1830A) in April 1966. This unit was to be the core of the AN/ASQ-114 Anti-Submarine Warfare (ASW) Lockheed P3-C aircraft. Others that I recall were Finley McLeod (department manager), George Kydd (I/O logic), John Bonnes (arithmetic), *Ralph Mattie* and *Al Schwartz* [memory], John Grape and LeRoy Vick [power supply], Dennis Paulinski [wire tabs], and me [PC board layout, mfg interface, and test software support.] Field Service Engineer, Jack Anderson, and Lowell flew on a P3 to deliver the first unit to the Naval Air Development Center in Johnsville, PA. This design had several innovations:

1. A 512 word bootstrap [core-rope] program had a designed-in self test program to test basic arithmetic, memory, and I/O functions before initiating program load from either a magnetic tape or drum unit.
2. It was the first to use a flat-pack integrated circuit [p/n 7901000 and 7901001] on a conduction cooled printed circuit card. Heat was conducted from the chip to the under chip heat sink to a 'T' bar at the top of the printed circuit card. A honeycombed heat exchanger pushed down on rows of these T-bars to transfer heat from the T-bars to air.
3. The 16k word core memory chassis had three access ports. When the main frame was configured with three or four memory chassis, the logic design would access up to three

memory banks simultaneously - an I/O transfer, an operand fetch or store, and the next instruction fetch.

4. A set of sixteen 6-bit page registers to extend the memory addressing from the basic 32k words to 131k words plus a memory protect feature.
5. A power failure detection mechanism to interrupt the program sequence so that critical data could be stored into core memory thereby facilitating quick mission resumption when the power returned to normal.

The first CP-901 was delivered to Johnsville, PA in September 1967 for software development. With S/N 499 delivery in 1993 this design was the longest production run of any other UNIVAC equipment! It is being phased out of operation by the CP-2044, an embedded emulation system whose development began in the early '90s. Although designed to address 131k words, the first 50 units were delivered with three memory chassis for 48k total. A fourth chassis was added to all units in the early '70s and in continuing production for a 64k operational system configuration. [lab]

Unisys Type 1832, AN/AYK-10 - Also called the S3A computer. This project started in 1969 with first delivery September 14, 1970. The AN/AYK-10 is a dual processor, dual I/O controller airborne version of the UYK-7 ISA with special I/O used for ASW missions aboard the Lockheed S3A carrier based aircraft. Innovations of this design: 1) dual mated film memory chassis running at 1.5 microseconds - each with 6 access ports. 2) a dual processor design interconnected so that if one CPU or one memory chassis or one I/O chassis failed, the system would continue to operate in a reduced capacity mode. Thus a reduced flight mission could continue - maybe just track 3 sono-buoys instead of 6 to 8, etc. 3) a unique frame design that fit at the rear of the S3A crew compartment - the wheels folded up almost against the sides of the Power Supply and third memory drawer.

Don Mager was the project engineer, Gary Bosworth and Gerry Shaw were two of the design engineers on this project. The operational software was developed by Sperry at the Valencia operations building. The first computer was delivered on 9/14/1970. There were a total of 205 of these computers built, including those for the CP-140. Sperry Univac DSD attendees at the first aircraft roll-out were:

- Jim Rapinac, General Manager, Special Programs, Salt Lake City
- Bill McGowan, Marketing Rep, LA office
- Ernie Hams, VP Program Management
- Dick Gehring, VP and General Manager
- Ken Oehlers, S-3A Engineering Director
- Dan Brophy, S-3A Program Manager
- Dewaine Osman, VP Marketing
- John Spearing, DSD Valencia Site Manager
- Norbert Kielbach, Marketing Rep, LA office