Project Report
ATC-81

Uplink Coverage Measurements in the Los Angeles Area for Passive BCAS

F. Nagy, Jr.

7 November 1977

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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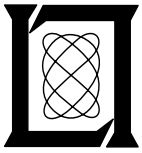

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16. Abstract

Uplink (1030 MHz) measurement results are presented, based on data recorded by the Airborne Measurement Facility of the M.I.T. Lincoln Laboratory during normal landings and take-offs at the LAX, Van Nuys, and San Diego airports. The data presented are relevant to current investigations of passive beacon-based collision avoidance systems and include: (1) the interrogator environment as received; (2) its division between FAA and other interrogators; (3) its dependence on aircraft height during landings and take-offs; and (4) the availability of P2 pulses of sufficient strength for PRF (pulse repetition frequency) tracking.

The number of interrogators was found to increase with the aircraft height at the rate of 2.5 to 3 interrogators per 1000 ft. P2 pulse tracking appears to be feasible down to 2000 ft. at LAX, and lower at San Diego.

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1.0 INTRODUCTION

On 30 September and 1 October of last year (1976), Lincoln Laboratory's Airborne Measurement Facility* (AMF) flew three missions of landings and take-offs in the LA area, one each at the Los Angeles International (LAX), Van Nuys, and San Diego airports. The missions were intended to answer a number of questions raised in connection with current investigations of passive BCAS (beacon-based collision avoidance systems**):

(1) How many interrogators make up the environment on 1030 MHz;

(2) How are these divided between FAA (terminal and en-route) and other (mostly military) interrogators;

(3) How does this environment depend on aircraft altitude during normal landings and take-offs; and

(4) What is the power level of the P2 pulses received from each interrogator as a function of altitude, and are enough P2 pulses detectable to allow continuous tracking of the Pulse Repetition Frequencies (PRF's) of the local FAA interrogators.

Most interrogators in an area interrogate at fixed rates (PRF's), differing from interrogator to interrogator. This allows the "tracking" of each interrogator, i.e., the separation of its interrogations from the sum total of interrogations received.

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*See Project Report ATC-60, 25 March 1976, "The Airborne Measurement Facility (AMF) System Description", G. V. Colby.

**See Bagnall and Kay, "A Review and Analysis of the Litchford Collision Avoidance System," October 1976, FAA-RD-77-1.

2.0 DATA COLLECTION AND PROCESSING

Figures 1 and 2 show the paths of the three AMF missions, superimposed on maps of the Los Angeles and San Diego areas. The maps are derived from the 1:500,000 Sectional Aeronautical Chart of the LA area, and indicate the principal interrogators observed in the data discussed below. Twenty seconds of data were recorded at each of the 46 aircraft positions shown. A receiver threshold of -74 dBm (referred to the AMF input*) was used everywhere except at position 16, where the threshold was -80 dBm.

The AMF Uplink Data Analysis Program was then run on each data segment. This program assembles received pulses into interrogations and suppressions, and counts each of these for the data span (here 20 sec), as well as in a normalized fashion (per sec). The program has a pulse repetition interval tracker, which separates the interrogation environment into the individual contributions by the interrogators of an area. The tracker can handle both fixed PRI's and also the 8-pulse stagger of the ATCBI-4's associated with the ASR-7's. The range of fixed PRI's tracked by the program is 1800 to 7200 μs, corresponding to PRF values from 455 to 114 interrogations per sec.

For each tracked interrogator, the program calculates the PRF, the scan period, the mode interlace, the total number of interrogations received over a 20-sec period, the peak mainbeam power, and the average angle of arrival of the interrogations (accurate to $\pm$ 30 deg.). Interrogations outside the range of fixed PRI's mentioned above, and those with PRI anomalies are not tracked, but are listed by the analysis program. Scan period, etc., may be determined

*In these measurements, the cable loss between the antenna and the front end of the AMF was 4 dB.

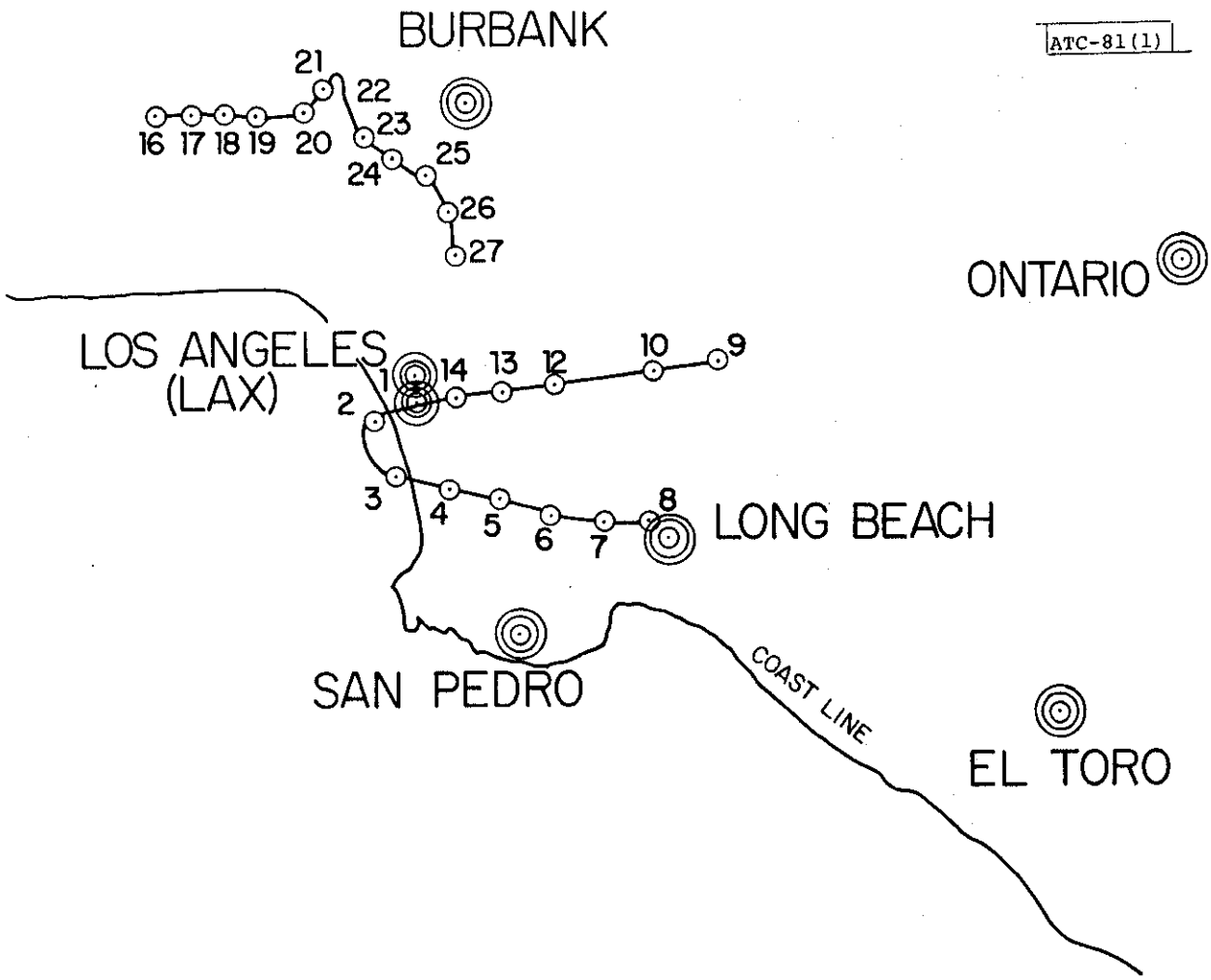


Fig. 1. Aircraft flight path for LA and Van Nuys missions.

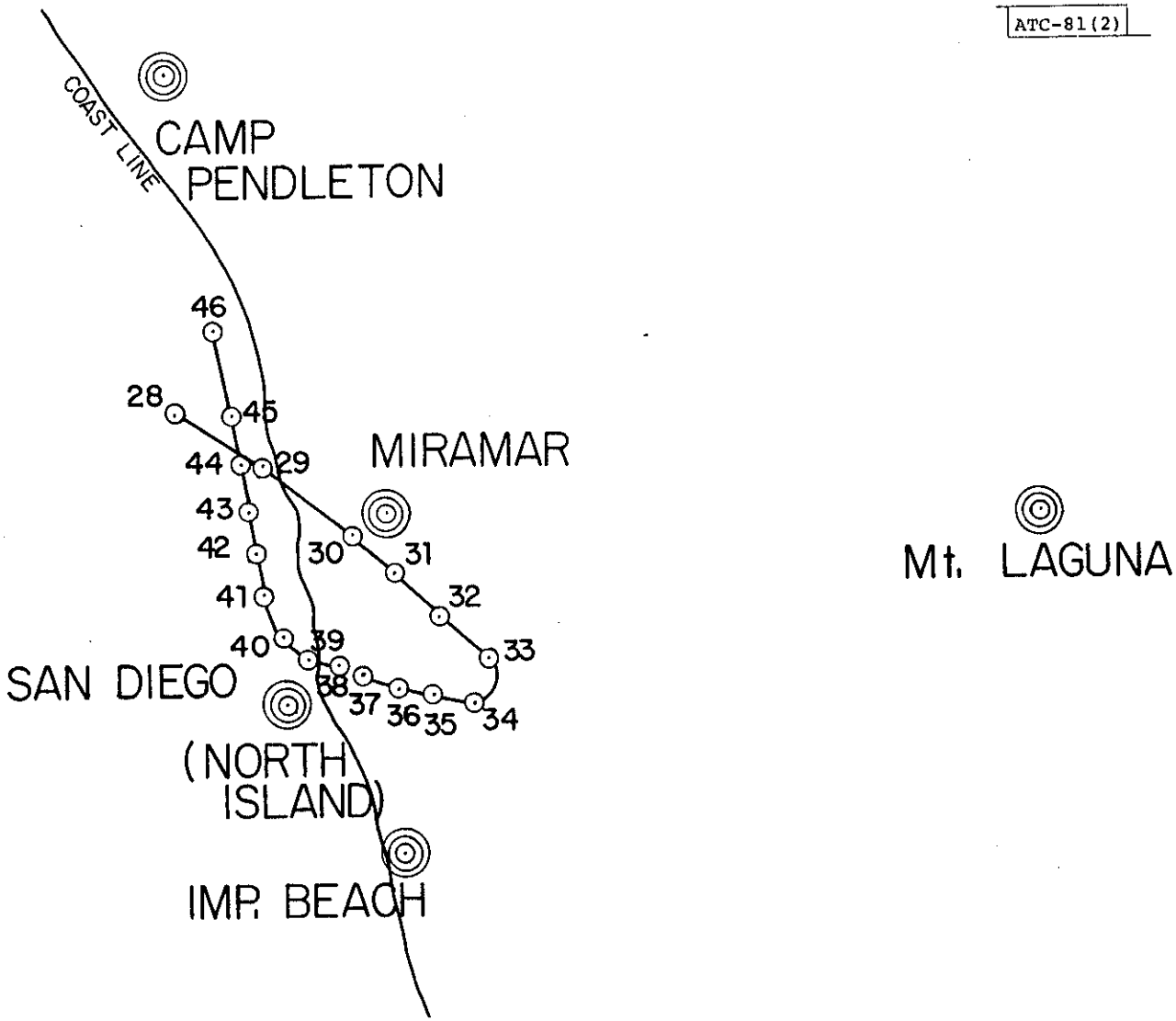


Fig. 2. Aircraft flight path for San Diego mission.

for some of these by hand, if necessary. The results tabulated below, however, refer only to interrogators tracked by the analysis program.

3.0 PRINCIPAL RESULTS

The "Interrogator Environment Tables" (Tables 1 through 9) contain all the information necessary to answer the four questions posed in Section 1. The first three tables show positions 1 - 14, the next three, positions 15 - 27, and the last three, positions 28-46, i.e., they refer to landings and take-offs at LAX, Van Nuys, and San Diego, respectively. The twenty right hand columns of these tables always represent the same twenty interrogators (9 FAA and 11 other), tracked by the analysis program.* The entries under the tracked interrogators alternate cyclically from table to table among:

(a) Number of interrogations received in 20 sec;

(b) Estimated angle of arrival of the interrogations;

(c) Maximum mainbeam power observed.

The first table of each environmental triplet (showing the number of interrogations in 20 sec) gives this additional information:

(a) Aircraft height above ground (HAG);

(b) Total interrogations per sec;

(c) Total suppressions per sec;

(d) Total pulses seen by AMF per sec.

This organization of the Environment Tables makes it possible to determine the number of interrogations, their direction, and their maximum mainbeam

*The notation 4*12AC denotes a mode interlace pattern of 11112222AAAACCCC.

Table 1

Los Angeles Take-off and Landing.
No. of Interrogations Received in 20 sec. (Tracked Interrogators Only).

		SCAN	MODE	NAME	PRF													
							R25 Take Off						Farthest East					R25 Land
OTHER INTERROGATORS		NONE	A	F	437.6													
		10.9	4*2C	E	308.6													
		3.77	4*12AC	D	224.6													
		3.80	4*12AC	C	335.9													
		3.84	4*2AC	B	378.0													
		3.86	AC	Norton	273.9				29	82	54	49	39	56	26			
		9.8	12AC	Camp Pendleton	292.1													
		5.6	4*12AC	A	242.7													
		11.2	4*12AC	San Diego	303.5				47	76	55	43	76	90	13			
		12.02	2*2ACA	San Clemente	334.9		8	64	48	85	89	30	59	68	32	10		
		9.67	1AC	San Nicolas	359.4		54	74	65	81	32	15	36	71	41	93	98	
FAA INTERROGATORS	TERMINAL	4.72	AAC	Long Beach	337.1		26	46	71	91	55	64	62	55	38	72	47	
		4.67	AAC	Miramar	350.0					44			32	80				
		6.00	AAC	Burbank	375.3			58	79	62	76	30	57	62	27	58		
		4.67	AAC	El Toro	390.2		23	53	59	56	83	55	36	54	61	57	75	
		4.67	AAC	Ontario	450.2				114	98	108	86	88	77	59	64		
		4.65	AAC	LAXASR7	378.6		239	60	91	123	80	59	61	61	96	210	261	
		4.67	AAC	LAX	405.2	28	147	52	106	73	98	79	54	52	76	168	128	23
	ENROUTE	12.02	2ACA	Mt. Laguna	330.2				17		35	7	9	42	28			
		12.00	2ACA	San Pedro	370.3		43	101	43	94	192	47	152	92	132	130	287	
TOTAL PULSES SEEN BY AMF PER SEC						2291	2290	2663	3465	3740	3349	2786	2767	2600	2861	2861	2455	1726
TOTAL SUPPRESSIONS PER SEC						205	423	779	939	1029	1074	774	776	732	915	828	678	167
TOTAL INTERROGATIONS PER SEC						194	77	117	178	193	195	158	140	72	51	66	71	123
AIRCRAFT HEIGHT ABOVE GROUND (FT)						100	1500	3200	4400	5700	6400	6400	7700	5700	3400	2600	2000	300
AIRCRAFT POSITION						1	2	3	4	5	6	7	8	9	10	12	13	14

Table 2

Los Angeles Take-off and Landing.
Estimated Angle of Arrival (deg). (Tracked Interrogators Only).

		SCAN	MODE	NAME	PRF	1	2	3	4	5	6	7	8	9	10	12	13	14
OTHER INTERROGATORS		NONE	A	F	437.6		R25 Take Off						Farthest East					R25 Land
		10.9	4*2C	E	308.6													
		3.77	4*12AC	D	224.6													
		3.80	4*12AC	C	335.9													
		3.84	4*2AC	B	378.0													
		3.86	AC	Norton	273.9				94	95	90	98	98	92	91			
		9.8	12AC	Camp Pendleton	292.1													
		5.6	4*12AC	A	242.7													
		11.2	4*12AC	San Diego	303.5				128	132	125	132	151	172	167			
		12.02	2*2ACA	San Clemente	334.9		203	176	184	186	187	200	204	213	206	208		
		9.67	1AC	San Nicolas	359.4		229	223	233	233	245	257	267	256	245	245	247	
FAA INTERROGATORS	TERMINAL	4.72	AAC	Long Beach	337.1		128	112	115	119	119	110	111	210	179	139	143	
		4.67	AAC	Miramar	350.0					125			130	156				
		6.00	AAC	Burbank	375.3			17	11	5	359	338	336	318	349	354		
		4.67	AAC	El Toro	390.2		115	116	116	131	117	125	106	137	135	112	105	
		4.67	AAC	Ontario	450.2				90	88	89	89	86	94	90	86		
		4.65	AAC	LAXASR7	378.6													
		4.67	AAC	LAX	405.2		56	18	345	316	292	302	318	272	278	275	274	
	ENROUTE	12.02	2ACA	Mt. Laguna	330.2			120	132		119	134	130	127	130			
		12.00	2ACA	San Pedro	370.3		175	130	162	183	208	280	245	244	236	209	198	
TOTAL PULSES SEEN BY AMF PER SEC																		
TOTAL SUPPRESSIONS PER SEC																		
TOTAL INTERROGATIONS PER SEC																		
AIRCRAFT HEIGHT ABOVE GROUND (FT)																		
AIRCRAFT POSITION						1	2	3	4	5	6	7	8	9	10	12	13	14

Table 3

Los Angeles Take-off and Landing.
Largest Mainbeam Power Seen (dBm). (Tracked Interrogators Only).

		SCAN	MODE	NAME	PRF	1	2	3	4	5	6	7	8	9	10	12	13	14
OTHER INTERROGATORS		NONE	A	F	437.6	Off							East					
		10.9	4*2C	E	308.6													
		3.77	4*12AC	D	224.6	R25 Take							Far theat					R25 Land
		3.80	4*12AC	C	335.9													
		3.84	4*2AC	B	378.0													
		3.86	AC	Norton	273.9				-56	-51	-52	-52	-58	-54	-64			
		9.8	12AC	Camp Pendleton	292.1													
		5.6	4*12AC	A	242.7													
		11.2	4*12AC	San Diego	303.5				-57	-59	-61	-63	-53	-58	-68			
		12.02	2*2ACA	San Clemente	334.9		-59	-47	-58	-57	-57	-59	-57	-51	-55	-66		
		9.67	1AC	San Nicolas	359.4		-51	-66	-53	-63	-57	-66	-61	-57	-54	-54	-49	
FAA INTERROGATORS	TERMINAL	4.72	AAC	Long Beach	337.1		-61	-48	-44	-44	-42	-36	-37	-44	-42	-46	-49	
		4.67	AAC	Miramar	350.0					-54			-57	-59				
		6.00	AAC	Burbank	375.3				-55	-46	-54	-55	-58	-56	-54	-64	-51	
		4.67	AAC	El Toro	390.2		-73	-58	-50	-56	-54	-56	-53	-50	-47	-53	-57	
		4.67	AAC	Ontario	450.2				-51	-53	-52	-55	-50	-49	-62	-56		
		4.65	AAC	LAXASR7	378.6		-37	-35	-31	-37	-43	-43	-48	-52	-43	-32	-33	
		4.67	AAC	LAX	405.2		-33	-31	-31	-38	-38	-41	-43	-46	-42	-29	-35	
	ENROUTE	12.02	2ACA	Mt. Laguna	330.2				-53		-63	-68	-62	-53	-58			
		12.00	2ACA	San Pedro	370.3		-40	-32	-31	-29	-30	-41	-35	-37	-38	-48	-63	
TOTAL PULSES SEEN BY AMF PER SEC																		
TOTAL SUPPRESSIONS PER SEC																		
TOTAL INTERROGATIONS PER SEC																		
AIRCRAFT HEIGHT ABOVE GROUND (FT)																		
AIRCRAFT POSITION																		

Table 4

Van Nuys Landing and Take-off.
Estimated Angle of Arrival (deg). (Tracked Interrogators Only).

	SCAN	MODE	NAME	PRF	15 Farthest West	16	17	18	19	20	21 R16 Land	22 R16 Take Off	23	24	25	26	27 Farthest SE
OTHER INTERROGATORS	NONE	A	F	437.6													
	10.9	4*2C	E	308.6													
	3.77	4*12AC	D	224.6													
	3.80	4*12AC	C	335.9													
	3.84	4*2AC	B	378.0													
	3.86	AC	Norton	273.9													11
	9.8	12AC	Camp Pendleton	292.1													
	5.6	4*12AC	A	242.7													
	11.2	4*12AC	San Diego	303.5													66
	12.02	2*2ACA	San Clemente	334.9	116	25	78	41	56					83	82	83	31
	9.67	1AC	San Nicolas	359.4	147	183	85	74	72					75	85	77	33
FAA INTERROGATORS — TERMINAL	4.72	AAC	Long Beach	337.1	46	22	31							46	64	42	60
	4.67	AAC	Miramar	350.0													
	6.00	AAC	Burbank	375.3	77	108	62	97	80	95	107	54	147	93	95	107	82
	4.67	AAC	El Toro	390.2	84	23	36	24	42	42			68	75		59	59
	4.67	AAC	Ontario	450.2	102	24								11	87	88	78
	4.65	AAC	LAXASR7	378.6	107	87	87	71	75				76	52	67	73	143
	4.67	AAC	LAX	405.2	150	107	76	33	125				105	118	91	100	68
FAA INTERROGATORS — ENROUTE	12.02	2ACA	Mt. Laguna	330.2												88	19
	12.00	2ACA	San Pedro	370.3	87	154	102	106	93	12	14		84	46	35	48	26
TOTAL PULSES SEEN BY AMF PER SEC					2441	4125	933	1071	1373	565	766	531	1644	2340	2293	2646	2772
TOTAL SUPPRESSIONS PER SEC					835	961	202	325	361	187	327	175	564	835	737	889	886
TOTAL INTERROGATIONS PER SEC					44	330	35	42	30	6	4	6	28	39	43	50	106
AIRCRAFT HEIGHT ABOVE GROUND (FT)					3600	3600	3000	2900	2500	1700	800	500	1700	2800	3800	3800	3800
AIRCRAFT POSITION					15	16	17	18	19	20	21	22	23	24	25	26	27

Table 5

Van Nuys Landing and Take-off.
Estimated Angle of Arrival (deg). (Tracked Interrogators Only).

		SCAN	MODE	NAME	PRF	15	16	17	18	19	20	21	22	23	24	25	26	27
							West											
		10.9	4*2C	E	308.6			Farthest				Land						SE
		3.77	4*12AC	D	224.6							R16						Farthest
		3.80	4*12AC	C	335.9								R16	Take Off				
		3.84	4*2AC	B	378.0													
		3.86	AC	Norton	273.9													88
		9.8	12AC	Camp Pendleton	292.1													
		5.6	4*12AC	A	242.7													
		11.2	4*12AC	San Diego	303.5													136
OTHER INTERROGATORS		12.02	2*2ACA	San Clemente	334.9	179	164	140	150	149					154	152	154	147
		9.67	1AC	San Nicolas	359.4	206	192	195	224	210					206	193	196	208
		4.72	AAC	Long Beach	337.1	125	105	118							120	130	145	139
		4.67	AAC	Miramar	350.0													
		6.00	AAC	Burbank	375.3	17	53	73	92	82	76	79	99	78	46	12	351	349
		4.67	AAC	El Toro	390.2	118	85	100	96	108	92			123	123		128	130
		4.67	AAC	Ontario	450.2	81	66								95	91	88	89
		4.65	AAC	LAXASR7	378.6													
		4.67	AAC	LAX	405.2	133	114	93	108	114				128	138	150	153	159
FAA INTERROGATORS	ENROUTE	12.02	2ACA	Mt. Laguna	330.2												136	132
		12.00	2ACA	San Pedro	370.3	141	120	116	112	137	136	154		129	131	143	146	141
TOTAL PULSES SEEN BY AMF PER SEC																		
TOTAL SUPPRESSIONS PER SEC																		
TOTAL INTERROGATIONS PER SEC																		
AIRCRAFT HEIGHT ABOVE GROUND (FT)																		
AIRCRAFT POSITION																		

Table 6

Van Nuys Landing and Take-off.
Largest Mainbeam Power Seen (dBm). (Tracked Interrogators Only).

		SCAN	MODE	NAME	PRF	15	16	17	18	19	20	21	22	23	24	25	26	27
OTHER INTERROGATORS		NONE	A	F	437.6													
OTHER INTERROGATORS		10.9	4*2C	E	308.6	Farthest West						R16 Land	R16 Take Off					Farthest SE
OTHER INTERROGATORS		3.77	4*12AC	D	224.6													
OTHER INTERROGATORS		3.80	4*12AC	C	335.9													
OTHER INTERROGATORS		3.84	4*2AC	B	378.0													
OTHER INTERROGATORS		3.86	AC	Norton	273.9													-67
OTHER INTERROGATORS		9.8	12AC	Camp Pendleton	292.1													
OTHER INTERROGATORS		5.6	4*12AC	A	242.7													
OTHER INTERROGATORS		11.2	4*12AC	San Diego	303.5													-56
OTHER INTERROGATORS		12.02	2*2ACA	San Clemente	334.9	-56	-69	-68	-71	-73					-57	-59	-57	-55
OTHER INTERROGATORS		9.67	1AC	San Nicolas	359.4	-52	-62	-67	-67	-64					-57	-58	-57	-62
FAA INTERROGATORS	TERMINAL	4.72	AAC	Long Beach	337.1	-63	-73	-75							-58	-51	-52	-51
FAA INTERROGATORS	TERMINAL	4.67	AAC	Miramar	350.0													
FAA INTERROGATORS	TERMINAL	6.00	AAC	Burbank	375.3	-49	-55	-50	-46	-50	-46	-44	-46	-48	-39	-39	-43	-45
FAA INTERROGATORS	TERMINAL	4.67	AAC	El Toro	390.2	-58	-67	-68	-70	-74	-75			-56	-59		-55	-53
FAA INTERROGATORS	TERMINAL	4.67	AAC	Ontario	450.2	-56	-72								-61	-56	-52	-51
FAA INTERROGATORS	TERMINAL	4.65	AAC	LAXASR7	378.6	-43	-55	-63	-66	-58				-48	-46	-47	-46	-39
FAA INTERROGATORS	TERMINAL	4.67	AAC	LAX	405.2	-39	-49	-64	-66	-55				-46	-43	-48	-38	-34
FAA INTERROGATORS	ENROUTE	12.02	2ACA	Mt. Laguna	330.2												-62	-59
FAA INTERROGATORS	ENROUTE	12.00	2ACA	San Pedro	370.3	-42	-50	-53	-48	-55	-66	-63		-46	-44	-46	-45	-44
TOTAL PULSES SEEN BY AMP PER SEC																		
TOTAL SUPPRESSIONS PER SEC																		
TOTAL INTERROGATIONS PER SEC																		
AIRCRAFT HEIGHT ABOVE GROUND (FT)																		
AIRCRAFT POSITION						15	16	17	18	19	20	21	22	23	24	25	26	27

Table 7

San Diego Landing and Take-off.
No. of Interrogations Received in 20 secs. (Tracked Interrogators Only).

Land (R27)

Group	SCAN	MODE	NAME	PRF	28	29	30	31	32	33	34	35	36	37
OTHER INTERROGATORS	NONE	A	F	437.6										
OTHER INTERROGATORS	10.9	4*2C	E	308.6	1274	501	441	399	267	181	220	177	165	
OTHER INTERROGATORS	3.77	4*12AC	D	224.6	70	69	96							
OTHER INTERROGATORS	3.80	4*12AC	C	335.9	70	65	62	25	54	14	84	35		7
OTHER INTERROGATORS	3.84	4*2AC	B	378.0	203	134	108	23	199	126	6	30	61	47
OTHER INTERROGATORS	3.86	AC	Norton	273.9										
OTHER INTERROGATORS	9.8	12AC	Camp Pendleton	292.1	197	123	113	66	56	56	24	62		
OTHER INTERROGATORS	5.6	4*12AC	A	242.7	290	125	228	312	321	142	143	144	110	201
OTHER INTERROGATORS	11.2	4*12AC	San Diego	303.5	117	100	218	65	327	207	90	126	143	127
OTHER INTERROGATORS	12.02	2*2ACA	San Clemente	334.9	88	71	64	81	29	68	30	68	26	63
OTHER INTERROGATORS	9.67	1AC	San Nicolas	359.4	62	63	65							
FAA INTERROGATORS – TERMINAL	4.72	AAC	Long Beach	337.1										
FAA INTERROGATORS – TERMINAL	4.67	AAC	Miramar	350.0	94	116	151	167	106	85	103	86	51	73
FAA INTERROGATORS – TERMINAL	6.00	AAC	Burbank	375.3										
FAA INTERROGATORS – TERMINAL	4.67	AAC	El Toro	390.2	65	64								
FAA INTERROGATORS – TERMINAL	4.67	AAC	Ontario	450.2										
FAA INTERROGATORS – TERMINAL	4.65	AAC	LAXASR7	378.6										
FAA INTERROGATORS – TERMINAL	4.67	AAC	LAX	405.2										
FAA INTERROGATORS – ENROUTE	12.02	2ACA	Mt. Laguna	330.2	52	64	41	24	78	74	28	74	45	48
FAA INTERROGATORS – ENROUTE	12.00	2ACA	San Pedro	370.3	55	30	39	44	37	12	16	35	41	
TOTAL PULSES SEEN BY AMF PER SEC					1483	1828	1884	1519	2097	2033	1907	1559	1783	1528
TOTAL SUPPRESSIONS PER SEC					303	415	319	270	431	354	389	138	250	243
TOTAL INTERROGATIONS PER SEC					156	107	186	142	155	147	118	116	90	92
AIRCRAFT HEIGHT ABOVE GROUND (FT)					5200	5300	4700	5200	5000	3300	2200	2100	1500	800
AIRCRAFT POSITION					28	29	30	31	32	33	34	35	36	37

Take Off (R27)

Group	SCAN	MODE	NAME	PRF	38	39	40	41	42	43	44	45	46
OTHER INTERROGATORS	NONE	A	F	437.6					3821	5903	5693	1231	5707
OTHER INTERROGATORS	10.9	4*2C	E	308.6									
OTHER INTERROGATORS	3.77	4*12AC	D	224.6						31	71		
OTHER INTERROGATORS	3.80	4*12AC	C	335.9		51	103	80					
OTHER INTERROGATORS	3.84	4*2AC	B	378.0									
OTHER INTERROGATORS	3.86	AC	Norton	273.9									
OTHER INTERROGATORS	9.8	12AC	Camp Pendleton	292.1			27	65	94		123	48	101
OTHER INTERROGATORS	5.6	4*12AC	A	242.7	6	137	326	661	661	360	255	11	155
OTHER INTERROGATORS	11.2	4*12AC	San Diego	303.5	155	668	483	188	77	27	46	37	96
OTHER INTERROGATORS	12.02	2*2ACA	San Clemente	334.9		29	75	87	81	42	36		78
OTHER INTERROGATORS	9.67	1AC	San Nicolas	359.4						33	54	27	49
FAA INTERROGATORS – TERMINAL	4.72	AAC	Long Beach	337.1									48
FAA INTERROGATORS – TERMINAL	4.67	AAC	Miramar	350.0		89	89	122	199	126	82	7	88
FAA INTERROGATORS – TERMINAL	6.00	AAC	Burbank	375.3									
FAA INTERROGATORS – TERMINAL	4.67	AAC	El Toro	390.2						54	60	9	37
FAA INTERROGATORS – TERMINAL	4.67	AAC	Ontario	450.2									
FAA INTERROGATORS – TERMINAL	4.65	AAC	LAXASR7	378.6									
FAA INTERROGATORS – TERMINAL	4.67	AAC	LAX	405.2								8	56
FAA INTERROGATORS – ENROUTE	12.02	2ACA	Mt. Laguna	330.2		22	60	61	71	63	38	20	59
FAA INTERROGATORS – ENROUTE	12.00	2ACA	San Pedro	370.3				30	34	24			87
TOTAL PULSES SEEN BY AMF PER SEC					310	2529	1553	1208	1745	1931	2120	2053	1802
TOTAL SUPPRESSIONS PER SEC					35	306	331	300	294	281	329	419	276
TOTAL INTERROGATIONS PER SEC					18	554	83	84	279	421	436	278	361
AIRCRAFT HEIGHT ABOVE GROUND (FT)					300	1300	2300	3200	3700	4700	5400	6400	6600
AIRCRAFT POSITION					38	39	40	41	42	43	44	45	46

Table 8

San Diego Landing and Take-off.
Estimated Angle of Arrival (deg). (Tracked Interrogators Only).

		SCAN	MODE	NAME	PRF	Land										Take Off								
OTHER INTERROGATORS		NONE	A	F	437.6															315	320	315	314	308
OTHER INTERROGATORS		10.9	4*2C	E	308.6	185	208	227	221	233	225	262	258	239										
OTHER INTERROGATORS		3.77	4*12AC	D	224.6	217	213	223													209	205		
OTHER INTERROGATORS		3.80	4*12AC	C	335.9	171	192	199	205	228		239	227		228 R27	R27	206	187	155					
OTHER INTERROGATORS		3.84	4*2AC	B	378.0	184	207	227	224	232	252		251	243	250									
OTHER INTERROGATORS		3.86	AC	Norton	273.9																			
OTHER INTERROGATORS		9.8	12AC	Camp Pendleton	292.1	340	318	290	293	299	322	323	329					315	336	334		336	334	3
OTHER INTERROGATORS		5.6	4*12AC	A	242.7	186	207	227	224	232	223	243	245	245	253		250	236	221	204	217	213		200
OTHER INTERROGATORS		11.2	4*12AC	San Diego	303.5	131	157	184	219	238	258	238	268	274	264	259	133	159	171	166	168	168	161	152
OTHER INTERROGATORS		12.02	2*2ACA	San Clemente	334.9	272	261	276	278	261	257	270	292	292	261		279	281	267	266	265	264		261
OTHER INTERROGATORS		9.67	1AC	San Nicolas	359.4	267	258	258													262	253	263	262
FAA INTERROGATORS	TERMINAL	4.72	AAC	Long Beach	337.1																			324
FAA INTERROGATORS	TERMINAL	4.67	AAC	Miramar	350.0	113	116	33	321	309	322	329	312	337	328		14	17	30	66	90	100	130	142
FAA INTERROGATORS	TERMINAL	6.00	AAC	Burbank	375.3																			
FAA INTERROGATORS	TERMINAL	4.67	AAC	El Toro	390.2	331	296														339	336	337	329
FAA INTERROGATORS	TERMINAL	4.67	AAC	Ontario	450.2																			
FAA INTERROGATORS	TERMINAL	4.65	AAC	LAXASR7	378.6																			
FAA INTERROGATORS	TERMINAL	4.67	AAC	LAX	405.2																		313	306
FAA INTERROGATORS	ENROUTE	12.02	2ACA	Mt. Laguna	330.2	104	91	93	84	79	65	50	72	100	100		89	83	80	83	78	93	90	90
FAA INTERROGATORS	ENROUTE	12.00	2ACA	San Pedro	370.3	307	309	302	307	308	310	308	305	299					317	322	322			318
TOTAL PULSES SEEN BY AMF PER SEC																								
TOTAL SUPPRESSIONS PER SEC																								
TOTAL INTERROGATIONS PER SEC																								
AIRCRAFT HEIGHT ABOVE GROUND (FT)																								
AIRCRAFT POSITION						28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46

Table 9

San Diego Landing and Take-off.
Largest Mainbeam Power Seen (dBm). (Tracked Interrogators Only).

		SCAN	MODE	NAME	PRF	R27 Land (aircraft positions 28–37)	Take Off R27 (aircraft positions 38–46)
OTHER INTERROGATORS		NONE	A	F	437.6		-55 -54 -57 -56 -52
		10.9	4*2C	E	308.6	-46 -47 -45 -49 -54 -66 -47 -42 -43	
		3.77	4*12AC	D	224.6	-63 -64 -63	-67 -62
		3.80	4*12AC	C	335.9	-55 -68 -61 -59 -53 -51 -51 -53	-47 -47 -56
		3.84	4*2AC	B	378.0	-51 -57 -48 -54 -46 -53 -50 -47 -53	
		3.86	AC	Norton	273.9		
		9.8	12AC	Camp Pendleton	292.1	-52 -59 -60 -55 -63 -59 -60	-56 -63 -60 -55 -57 -64
		5.6	4*12AC	A	242.7	-45 -53 -46 -51 -42 -61 -41 -39 -39 -50	-42 -39 -44 -42 -44 -45 -49
		11.2	4*12AC	San Diego	303.5	-53 -46 -44 -45 -45 -56 -55 -42 -39 -38 -53	-46 -33 -40 -44 -46 -48 -49 -50 -53
		12.02	2*2ACA	San Clemente	334.9	-55 -53 -54 -52 -59 -68 [illegible] -51 -51 -54	-47 -51 -52 -54 -56 -56 -56
		9.67	1AC	San Nicolas	359.4	-65 -59 -49	-58 -65 -56 -63
FAA INTERROGATORS	TERMINAL	4.72	AAC	Long Beach	337.1		-62
		4.67	AAC	Miramar	350.0	-45 -41 -29 -35 -37 -49 -47 -60 -50 -57	-48 -44 -42 -43 -41 -46 -49 -50
		6.00	AAC	Burbank	375.3		
		4.67	AAC	El Toro	390.2	-59 -60	-58 -57 -68 -64
		4.67	AAC	Ontario	450.2		
		4.65	AAC	LAXASR7	378.6		
		4.67	AAC	LAX	405.2		-58 -60
	ENROUTE	12.02	2ACA	Mt. Laguna	330.2	-43 -41 -44 -44 -43 -45 -48 -47 -45 -54	-59 -50 -50 -48 -48 -51 -41 -49
		12.00	2ACA	San Pedro	370.3	-57 -57 -61 -57 -62 -69 -69 -59 -65	-56 -53 -55 -49
TOTAL PULSES SEEN BY AMF PER SEC							
TOTAL SUPPRESSIONS PER SEC							
TOTAL INTERROGATIONS PER SEC							
AIRCRAFT HEIGHT ABOVE GROUND (FT)							
AIRCRAFT POSITION						28 29 30 31 32 33 34 35 36 37	38 39 40 41 42 43 44 45 46

power for a given interrogator and aircraft position. For example (from Tables 1, 2, and 3) at position 8, the AMF received 152 interrogations in 20 seconds from San Pedro, arriving from the southwest (245 deg) with a maximum mainbeam power of -35 dBm (in a total environment of 140 interrogations, 776 suppressions, and 2767 pulses per sec).

Although the P2 powers are not output by the analysis program directly, the P2 power may be estimated to have a power level approximately 20 dB below the mainbeam power. For the San Pedro example, the P2 power level would be about -55 dBm.

3.1 Interrogator Population

The Environment Tables answer Questions (1) and (2) of Section 1 (about the environment on 1030 MHz, and about its division between FAA and other interrogators) by counting columns with entries in them. This counting has been done in Table 10, which shows the number of interrogators and their types seen at each position, and the aircraft height at those positions.

Figure 3 presents plots of the corresponding three parts of Table 10 for LAX, Van Nuys, and San Diego, showing the number of different types of interrogators versus height (above ground).

3.2 Altitude Dependence

The plots of Figure 3 answer Question (3) of Section 1 (about the dependence of the environment upon altitude). Note that the FAA interrogators, which predominate in the LAX and Van Nuys areas, are less significant in the San Diego area.

Figure 4 presents another view of the height-type-number dependence. In this figure, landings have been separated from take-offs, and plotted as

Table 10

Number of Tracked Interrogators (FAA and Other) as a Function of Height Above Ground.

AIRPORT	Aircraft Position	Height Above Ground (ft)	FAA Interrogators	Other Interrogators	Total Interrogators
LAX	1	100	1	0	1
	2	1500	5	2	7
	3	3200	6	2	8
	4	4400	8	4	12
	5	5700	8	4	12
	6	6400	8	4	12
	7	6400	8	4	12
	8	7700	9	4	13
	9	5700	9	4	13
	10	3400	8	4	12
	12	2600	7	2	9
	13	2000	5	1	6
	14	300	1	0	1
VAN NUYS	15	3600	7	2	9
	16	3600	7	2	9
	17	3000	6	2	8
	18	2900	5	2	7
	19	2500	5	2	7
	20	1700	3	0	3
	21	800	2	0	2
	22	500	1	0	1
	23	1700	5	0	5

AIRPORT	Aircraft Position	Height Above Ground (ft)	FAA Interrogators	Other Interrogators	Total Interrogators
VAN NUYS	24	2800	7	2	9
	25	3800	6	2	8
	26	3800	8	4	12
	27	3800	8	4	12
SAN DIEGO	28	5200	4	9	13
	29	5300	4	9	13
	30	4700	3	9	12
	31	5200	3	7	10
	32	5000	3	7	10
	33	3300	3	7	10
	34	2200	3	7	10
	35	2100	3	7	10
	36	1500	3	5	8
	37	800	2	5	7
	38	300	0	2	2
	39	1300	2	4	6
	40	2300	2	5	7
	41	3200	3	5	8
	42	3700	3	5	8
	43	4700	4	6	10
	44	5400	3	7	10
	45	6400	4	5	9
	46	6600	6	6	12

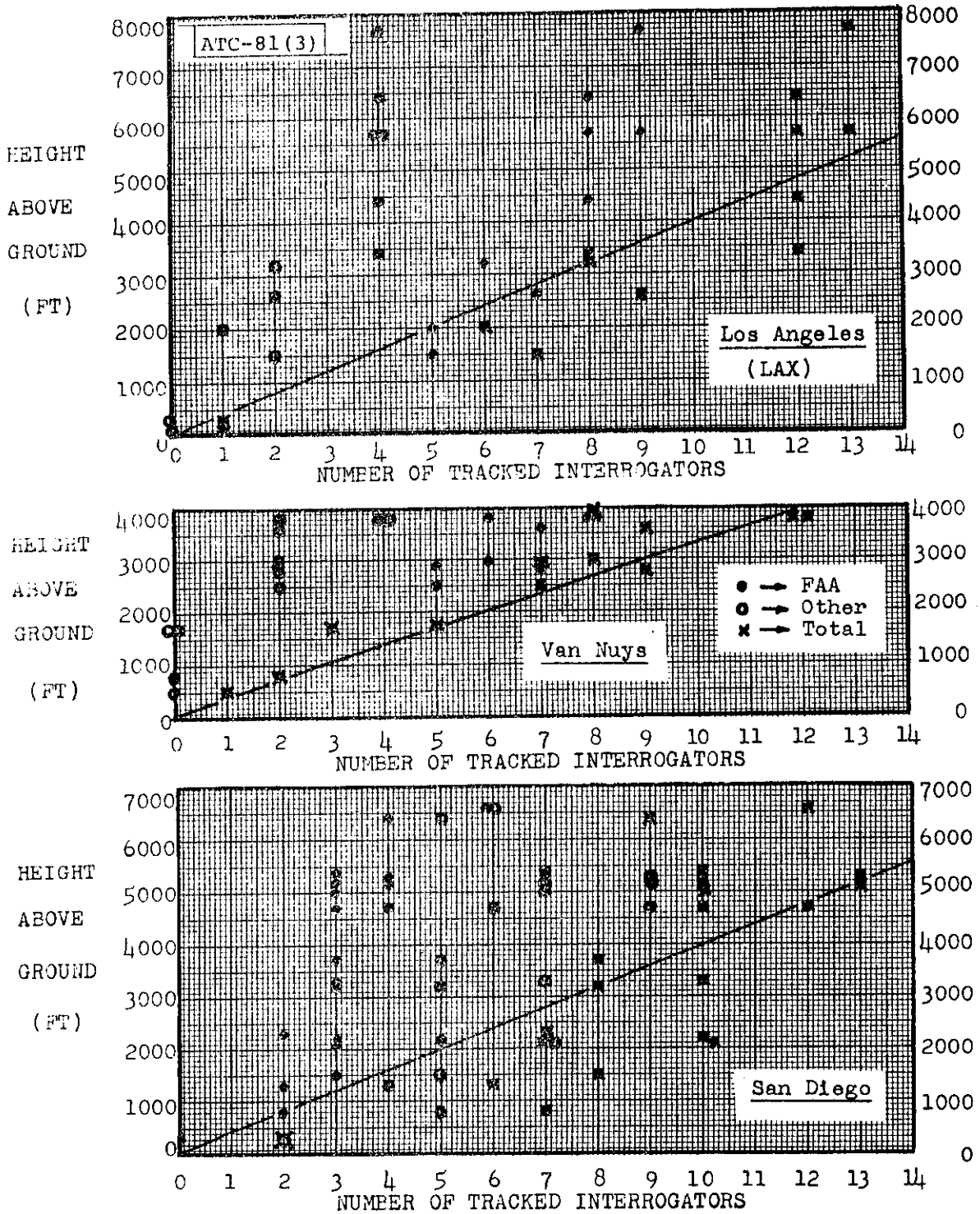


Fig. 3. Number of tracked interrogators as a function of height.

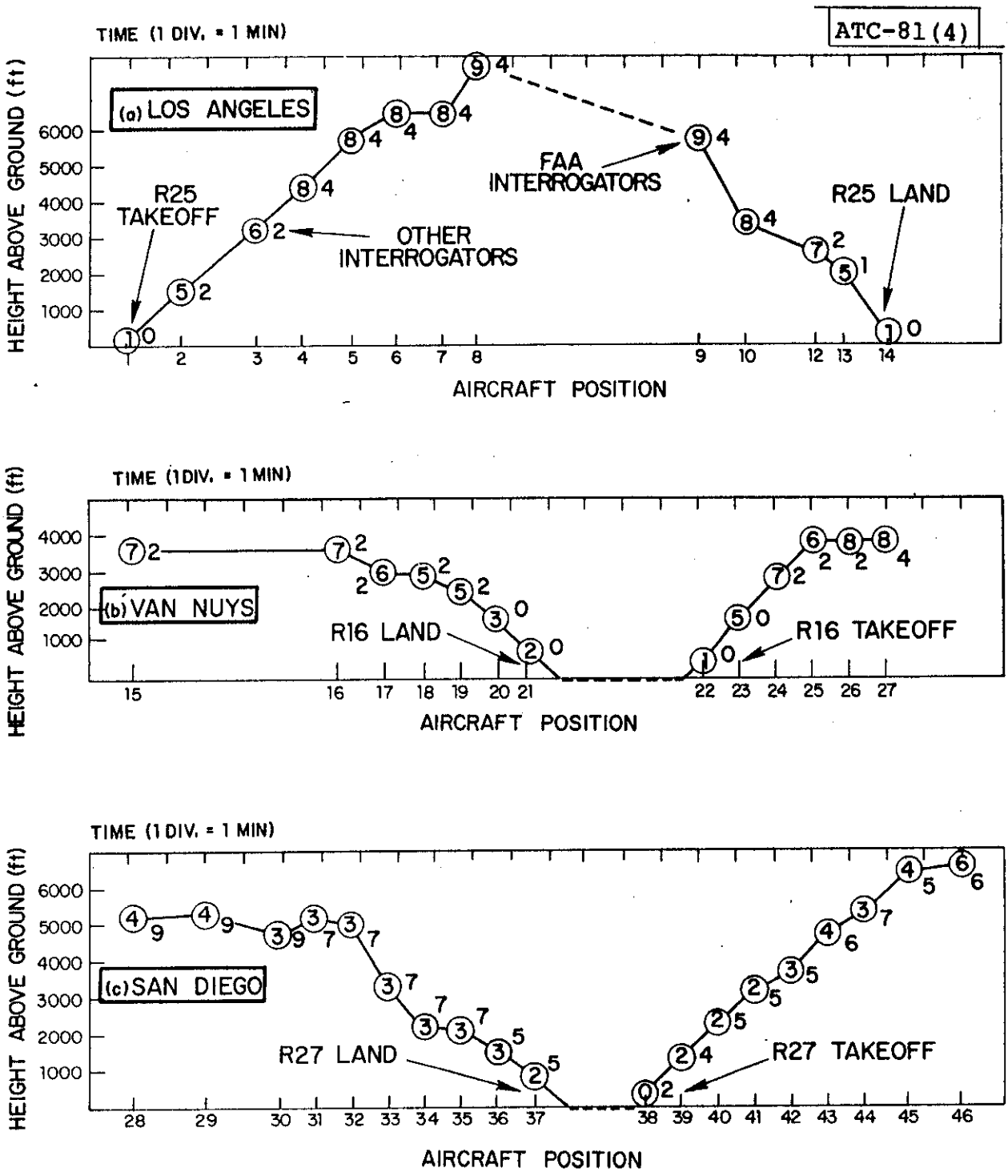


Fig. 4. Number of interrogators tracked during landings and take-offs vs altitude.

a function of time. For each position, a small circle centered at the proper height (above ground) contains the number of FAA interrogators which were tracked there. The number of other interrogators tracked at each altitude is written next to the circle.

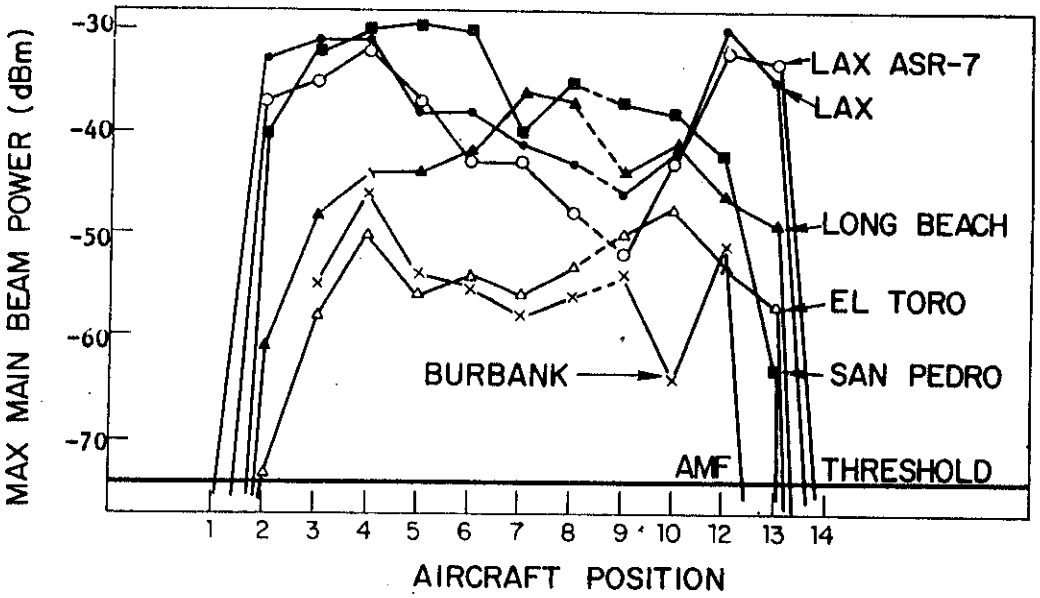
3.3 P2 Pulse Tracking

Figure 5 presents data relevant to the problem of passive tracking of P2 pulses, posed in Question (4) of Section 1. Part (a) of the figure is a plot of the maximum power received from the FAA interrogators near LAX. The plotted values have been obtained from six selected columns of Table 3. Since the corresponding plot of P2 pulse power would be approximately 20 dB below the curves shown (as explained in paragraph 3.0) the figure can be used to answer Question (4) about the sufficiency of trackable P2 pulses for any assumed receiver threshold. Part (b) of Figure 5 is similar to Part (a), except that it refers to the San Diego area. Here selected values of Table 9 have been plotted.

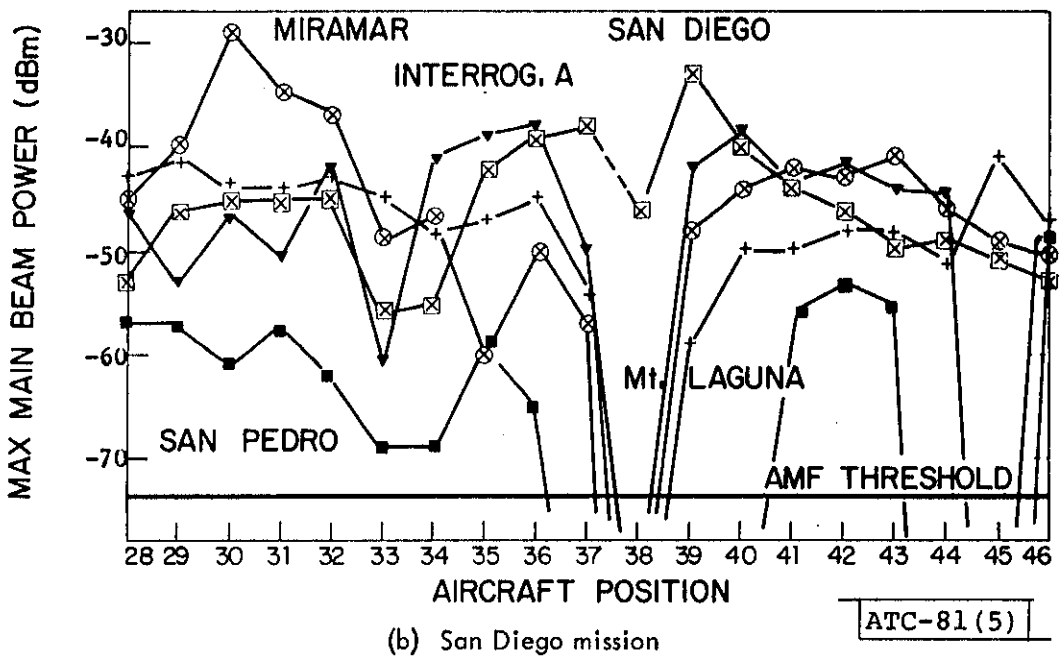
4.0 ADDITIONAL RESULTS

4.1 ECAC File Adjustments

The AMF analysis program does not automatically associate interrogators of an area with the different PRFs detected and tracked by the program. This assignment of PRFs to real interrogators must be done manually. The usual method of doing this is to find the PRF in the ECAC Interrogator File nearest to the PRF tracked by the program, and then check the other parameters. When identification is made, the interrogator location (latitude and longitude)



(a) LAX mission



(b) San Diego mission

Fig. 5. Maximum power levels of received interrogations.

in the ECAC Interrogator File is further checked for consistency with the measured angle of arrival, measured mainbeam power, and number of interrogations received.

The identification process is often hampered by inaccuracies in the Interrogator File. Fourteen of the 20 PRF's tracked by the program have been identified with real interrogators (as indicated by the names in the Environment Tables) despite the fact that 9 of the 14 appeared in the Interrogator File with one or more parameters in need of adjustment (see Table 11).

4.2 Unidentified Interrogators

Unidentified interrogators (called A, B, C, D, E, and F in the Environment Tables) must be "located" entirely by the measured parameters given in the tables, most of all, by the angle of arrival. This procedure locates interrogators A, B, E (and, probably, C as well) somewhere southwest of the San Diego path, off the coast, perhaps 10 nm west of North Island. Interrogator D is probably much further off the coast, southwest (215 deg) of San Diego. The omni-directional interrogator F is somewhere northwest (315 deg) of San Diego, perhaps off the coast near Camp Pendleton.

4.3 Environment Table Notes

(a) The large number of interrogations per sec at positions 1 and 14 (see Table 1) results from the fact that these positions are just off the ground, over the runways at LAX where reflected suppressions combine into false Mode 1 and 2 interrogations.

(b) At positions 4 through 8, an omnidirectional interrogator on Mode 2, with a PRI of 4071 μs followed by one of 20358 μs, regularly, contri-

Table 11

AMF-Measured Interrogator Parameters at Variance with 2-5-76 ECAC File.

INTERROGATOR	PARAMETER OF DIFFERENCE	ECAC FILE 2-5-76	MEAS'D VALUE 10-1-76
San Pedro	RPM	6	5
Mt. Laguna	PRF	241	330.2
Long Beach	PRF MODE	415 A	337.1 AAC
Burbank	RPM	15	10
San Nicolas Is.	MODE	A	1AC
San Clemente Is.	PRF MODE RPM	300 A 16	334.9 4*2ACA 5
San Diego	PRF MODE RPM	300 A 20	303.5 4*12AC 5.5
Cp. Pendleton	PRF MODE	295 A	292.1 12AC
Norton AFB	PRF MODE	275 A	273.9 AC

buted about 60 interrogations per sec. It seemed to be located just south of Long Beach. It is an interrogator on 4071 μs (PRF = 221) which is on the air 2 times, and then off the air 4 times, repeatedly.

(c) At position 16 (see Table 4), the 330 interrogations per sec are mainly due to an interrogator on 320 PRF, to the southwest (mode interlace 1/2/A, scan period = 7.8 sec). Many sidelobe interrogations from this interrogator were received, partially because of the enhanced receiver sensitivity used at this one position (-80 dBm instead of the usual -74 dBm).

(d) At position 27, most of the 106 interrogations per sec come from an interrogator with an unstable PRI of 5052 $\pm$ 2 μs interrogating on Mode 2, located somewhere to the west (about 960 interrogations in 20 sec).

(e) An omnidirectional interrogator on 100 PRF (Mode A) was observed from position 29 to position 36 of the San Diego mission. Many interrogations (1200 to 1800 in 20 sec) were received from it during positions 30 through 34. Its angles of arrival seem to place it on the coast between North Island and Imperial Beach.

(f) The excessive number of interrogations at position 39 (554 per sec) comes from another omnidirectional interrogator seen only at this one point. Its PRF (910 per sec) is unusually high. Its Mode A interrogations are coming from the southeast at -70 dBm. It might be located somewhere between Tijuana and Imperial Beach (about 800 interrogations in 20 sec).

(g) Some interrogations with irregular PRI have been seen during these three missions. An interrogator ("Z1") with a 26- μs jitter in its PRI (8687 μs followed by 8713 μs, repeatedly) was seen through most

of the Van Nuys mission, contributing 2 to 3 interrogations per sec (mode interlace A/C, scan = 3.72 sec). Interrogator Z1 is presumably located just south of LAX.

(h) A second interrogator ("Z2") with highly irregular PRI of period 9 (full period: 6810, 2831, 2831, 3051, 2831, 2831, 3881, 2831, 2831 μs) was noted through the first part of the San Diego mission (positions 28-40), contributing perhaps 7-8 interrogations per sec (Mode C, scan = 7.78 sec). Interrogator Z2 is probably on the coast south of Long Beach.

(i) Another interrogator ("Z3") with irregular PRI of period 7 (full period: 4107, 4107, 4107, 4107, 4117, 4900, 4094 μs) was noted contributing 3 interrogations per sec during positions 24 - 27 of the Van Nuys flight (mode interlace 1/2/A/C, scan = 5.8 sec). Its interrogations were arriving from the southeast at a rather high level (-40 dBm). Interrogator Z3 might be located near Inglewood.

(j) Finally, a fourth interrogator ("Z4") with irregular PRI of period 7 (full period: 4607, 5692, 3354, 4143, 4916, 5107, 5108 μs) was seen at positions 17 and 18. Interrogator Z4 contributed 2 to 3 interrogations per sec (mode interlace 1/2/A/C, scan = 5.87 sec) at a low power level (-70 dBm), arriving from the southeast.

5.0 CONCLUSIONS

The AMF measurements indicate a visible interrogator population increasing with height during normal landings and take-offs at the three selected LA area airports (see Table 10 and Figures 3 and 4). The number of FAA and other interrogators visible to the AMF increases rapidly with aircraft height

and then tends to become constant above an altitude of approximately 3000 ft. The actual number of interrogators seen and the FAA/other ratio are area dependent.

The behavior of FAA interrogators is generally predictable from the ECAC Interrogator File for the area, but other interrogators are either on or off according to time of day and day of the week, and a significant number of interrogators not included in the ECAC file are generally received. Although the total number of received interrogators is not exactly a linear function of altitude (see Fig. 3), a linear function does provide a first-order approximation for altitudes up to about 6000 ft., where the rate is 2.5 interrogators per 1000 ft. for LAX and San Diego, and 3 interrogators per 1000 ft. for Van Nuys.