Ejection Success Prediction Based on Historical Data

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Terrain Clearance Requirements

- Tables – usually based on some ideal of existing performance

MIL-S-18471G(AS)

TABLE II. Escape system ground clearance requirements envelope cross section for single seat aircraft. 1/ , 2/

Aircraft velocity conditions 3/			Worst case vertical clearance above ground level (in feet) at aircraft bank angles of: 3/, 6/			
Airspeed KEAS 4/	Dive angle degrees	Sink rate fpm	0°	45°	90°	180°
0	0	0	0 9/	0	20	170
		2,000	0	0	70	200
		6,000	80	90	160	260
		10,000	170	175	220	300
130	0	0	0 9/	0	10	120
		2,000	0	0	30	160
		6,000	30	40	110	210
		10,000	110	120	180	270
225	0	0	0 9/	0	10	90
		2,000	0	0	20	110
		6,000	10	20	100	180
		10,000	90	110	160	230
600 5/	0	0	0 9/	0	40	140
		2,000	0	0	90	190
		6,000	30	50	180	280
		10,000	130	150	240	370
50	20	7/	0 8/	0	70	190
0	30	7/	0	0	50	170
	60		0	20	70	130
	90		80	80	80	80
130	30	7/	80	90	150	230
	60		210	220	250	290
	90		280	280	280	280
225	30	7/	130	150	200	270
	60		300	310	330	380
	90		390	390	390	390
450	30	7/	500	520	590	670
600 5/	30	7/	560	570	660	750
	60		1050	1060	1110	1150
	90		1270	1270	1270	1270

1/ Recovery parachute shall achieve an average descent velocity as specified in 3.2.2.6.1e, except as permitted in 9/ .

MIL-DTL-9479E (USAF)

3.4.4 Design escape capability. Unless otherwise specified, the seat system shall be designed to provide safe ejection as specified below, all of which shall be verified by analysis (see 4.5.1, 4.5.8):

a. Aircraft performance envelope - All flight attitudes and load factors within the design limit and velocity-attitude envelope of the aircraft, unless otherwise stated.

b. Zero altitude (level flight) - From zero airspeed to maximum velocity of the aircraft, unless otherwise stated.

c. Low level - At low altitude, adverse attitude conditions including those specified in table I.

TABLE I. Low Level Escape Performance[1]

Altitude (Feet)	Velocity (Knots)	Attitude	
		Fore and Aft	Roll Angle
0[2]	120	Level	60°
200	150	Level	180°
300[3]	150	Level	0°
500	200	60° Nosedown	0°
500	450	30° Nosedown	0°
550	200	60° Nosedown	60°
600	250	45° Nosedown	180°

[1] The cited conditions are at the initiation of the ejection sequence
[2] Aircraft impact with the ground occurs at instant of seat-aircraft separation
[3] 10,000 foot per minute sink rate

NACES P³I

- Naval Aircrew Common Ejection Seat (Mk14)
- Pre-Planned Product Improvement
- Two-phase study ran from 1996-2000
- USN came up with the idea of using historical data for terrain clearance requirements

NACES P³I

- 1342 USN ejections - variety of aircraft and seat types
- 157 Out-of-Envelope Ejections
- 48 where conditions known
- Used in trade study to determine how many lives a candidate configuration would have saved
- A very motivational requirement

Case	Speed	Altitude	Dive	Bank	Sink
#	KEAS	feet	Ang-deg	Ang-deg	Rate-fpm
1	170	25	10(-10)	-80	2000(0)
2	125	200	10	-90	2200
3	125	250	10	-90	2200
4	165	75	15	-25	4320
5	165	45	15	-30	4320
6	90	85	10	90	1580
7	90	75	10	125	1580
8	125	200	-10	80	0
9	125	165	-10	85	0
10	0	60	40	-90	0
11	0	60	40	-90	0
12	200	100	10(30)	-99	0
13	225	200	10(40)	90	4000(2000)
14	225	200	-40	90	-2000
15	75	15	14	65	1840
16	75	20	14	65	1840
17	125	60	0	-110	2000
18	50	100	45	180	2000
19	100	100	10	-75	2500
20	50	0	10	-20	0
21	50	0	10	-20	0
22	60	0	-10	20	0
23	90	20	3	3	900
24	100	100	30	35	5000(1500)
25	70	25	-10	30	100
26	200	50	-10	-1	3000
27	150	20	10	-80	900
28	90	30	20	0	1600
29	40	60	10	0	20
30	275	300	35	-45	16000(4000)
31	275	200	35	-45	-4000
32	170	100	0	70	2000
33	120	200	60	75	3000
34	220	140	10	100	2000
35	220	175	10	75	2000
36	150	80	15	-90	3000
37	150	100	15	-35	3000
38	125	100	-20	-50	0
39	125	100	-20	-130	0
40	125	100	-20	-130	0
41	165	30	-30	15	0(3000)
42	125	105	15	80	3280
43	125	150	15	90	3280
44	125	150	15	90	3280
45	90	150	-10	70	0(2000)
46	150(100)	10	5	50	1000
47	130	80	25	-110	2000(500)
48	188	110	16	120	3000

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  - NACES saved 50%, 4th Gen 95%

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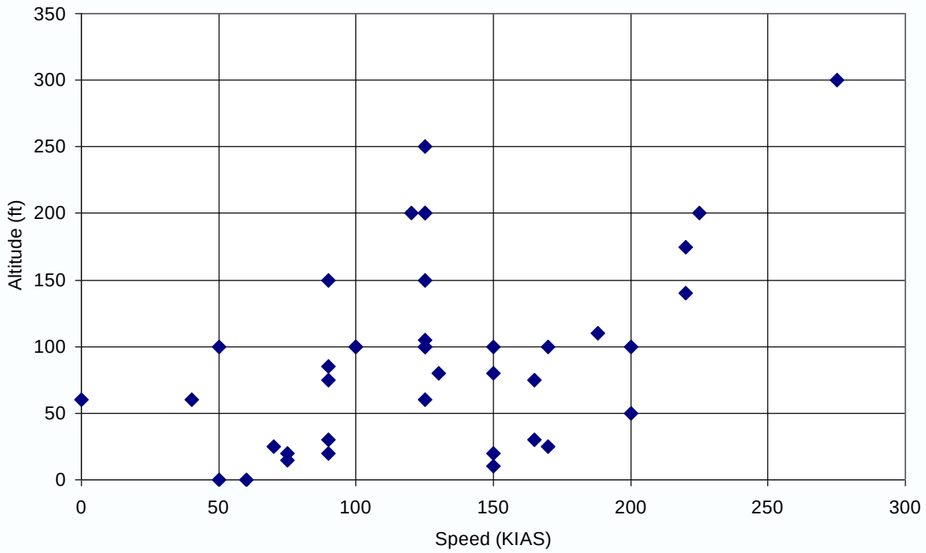
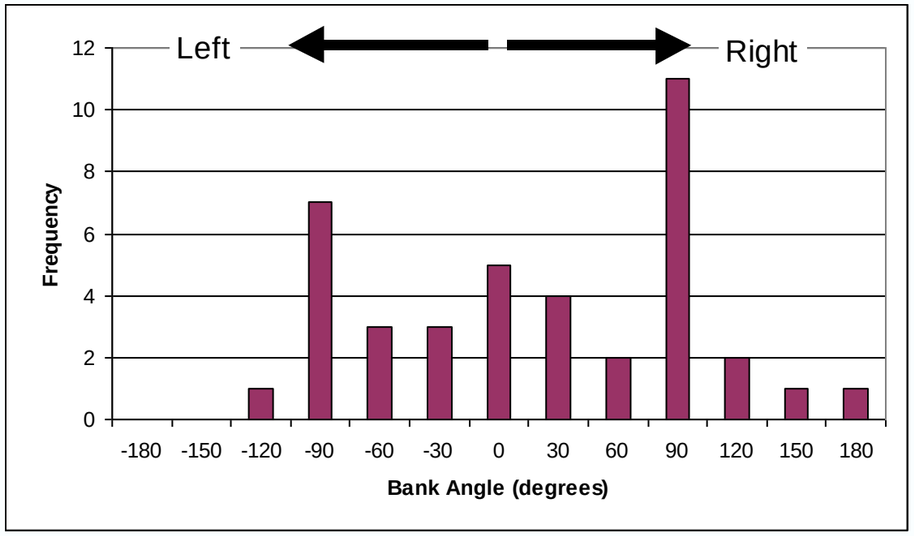
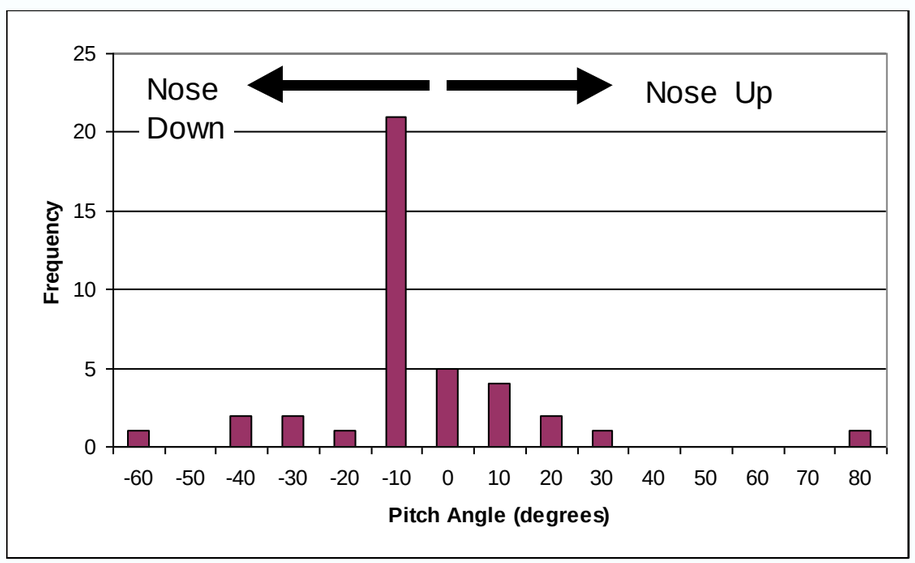
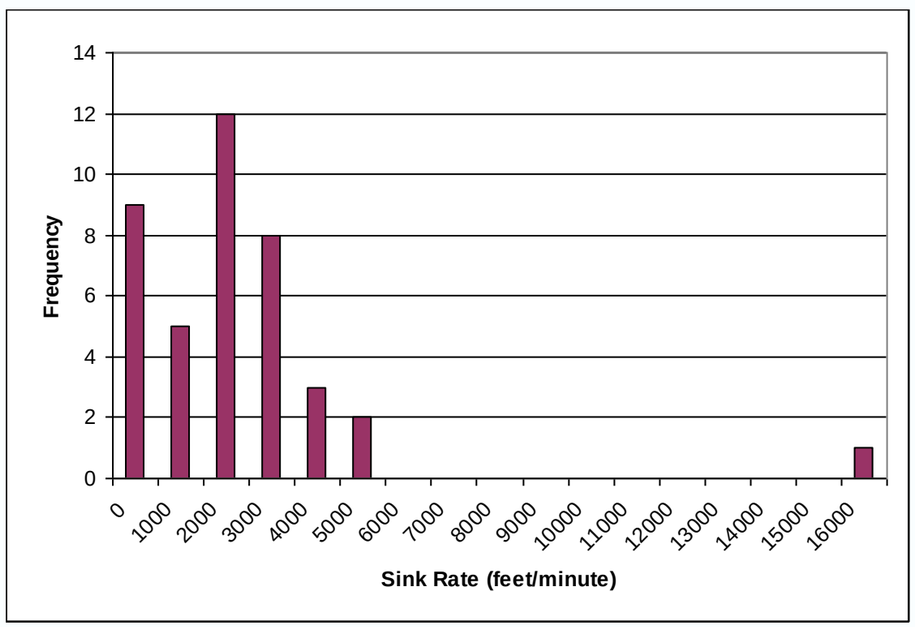
NACES P³I









MBA Database

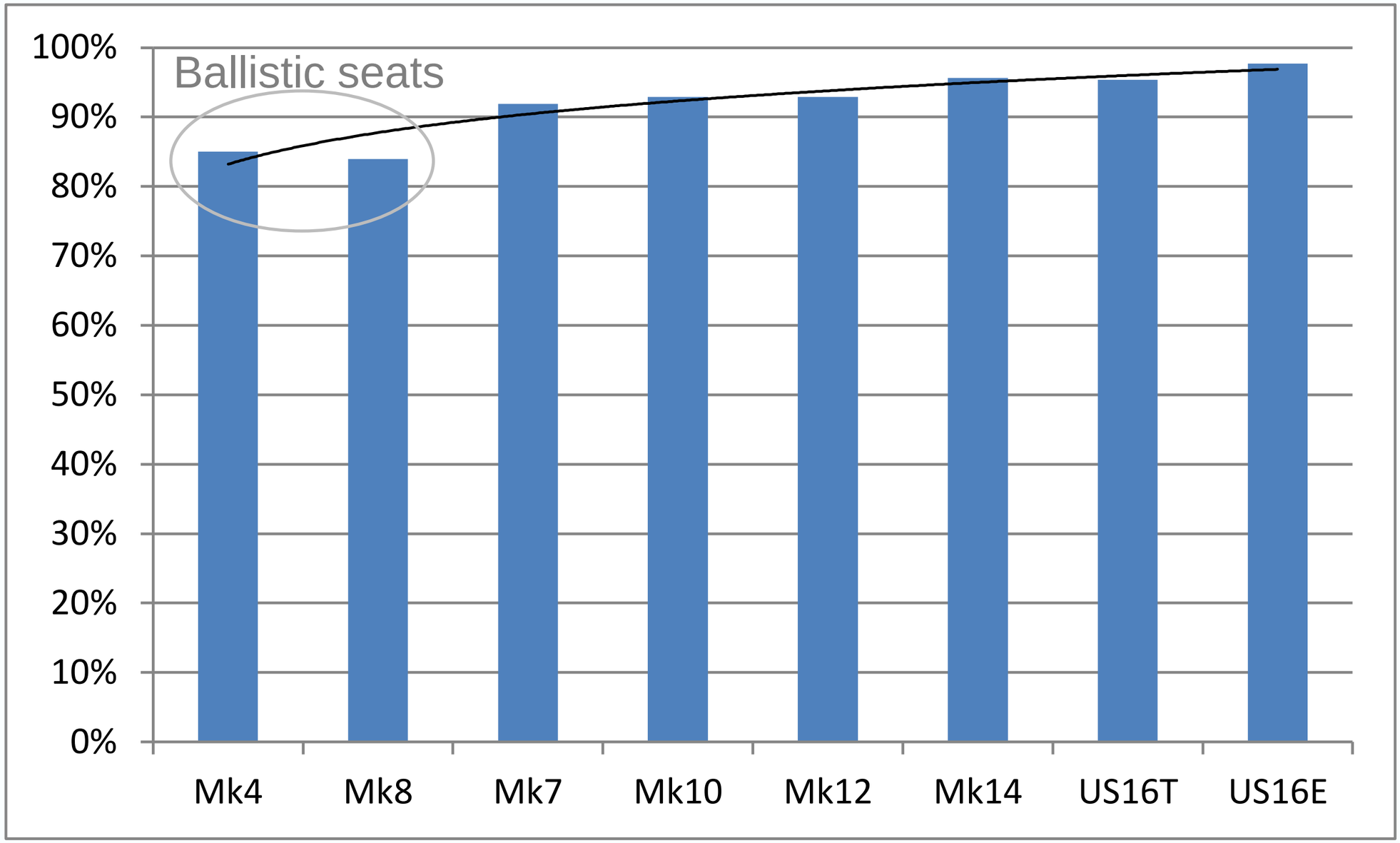
- Carried over idea to all ejections in Martin-Baker ejection database
- Objective being to obtain a probability of success for being in/out of envelope
- >7000 ejections
- About half where conditions known

… please remember that past performance is not necessarily a guide to future performance …

MBA Database Simulations

- Set up simulations to run all known cases
- Assumed statistics of known cases did not differ from all unknown cases
- Ran for a number of existing seat types

Predictions for probability of being in-envelope



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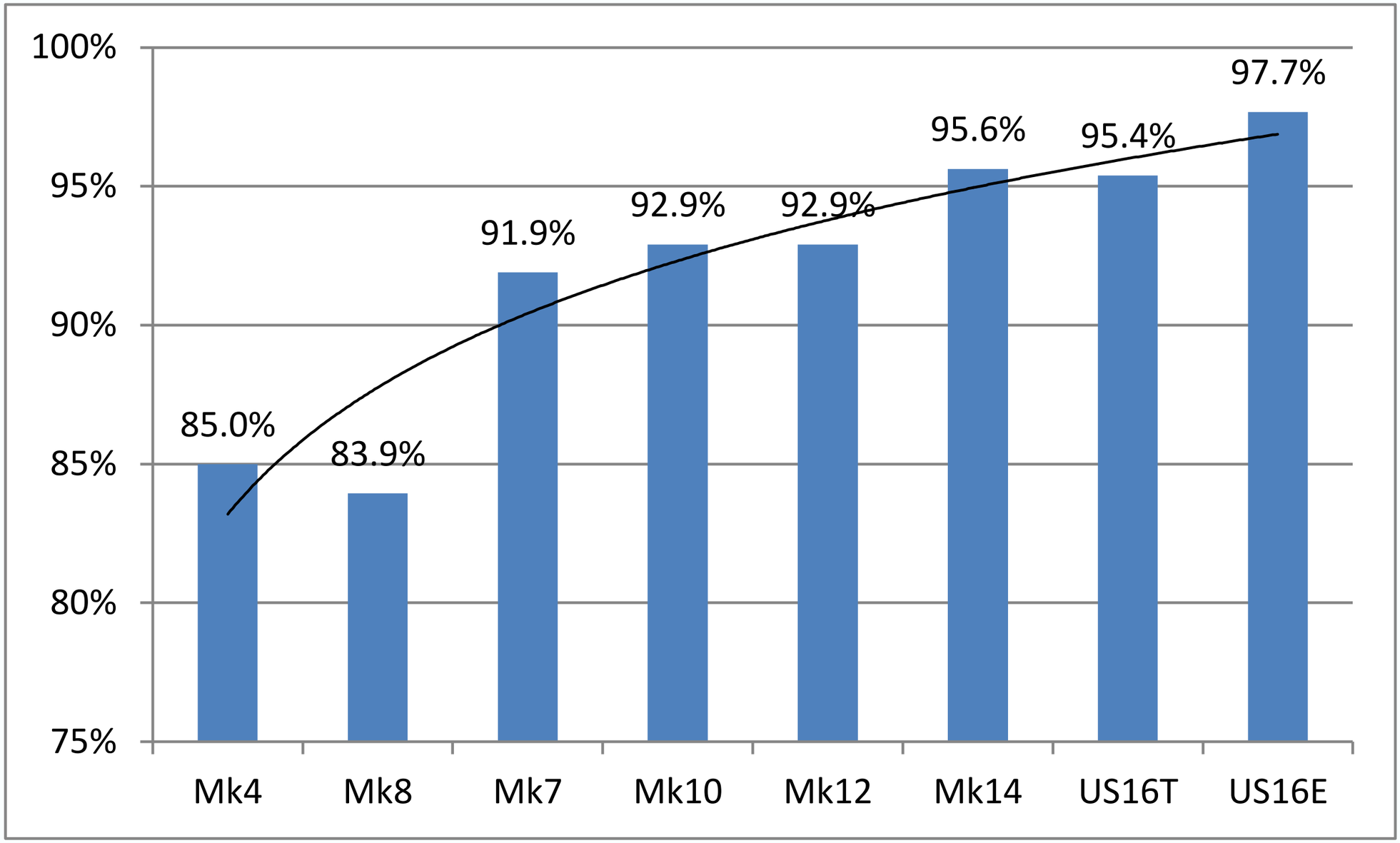
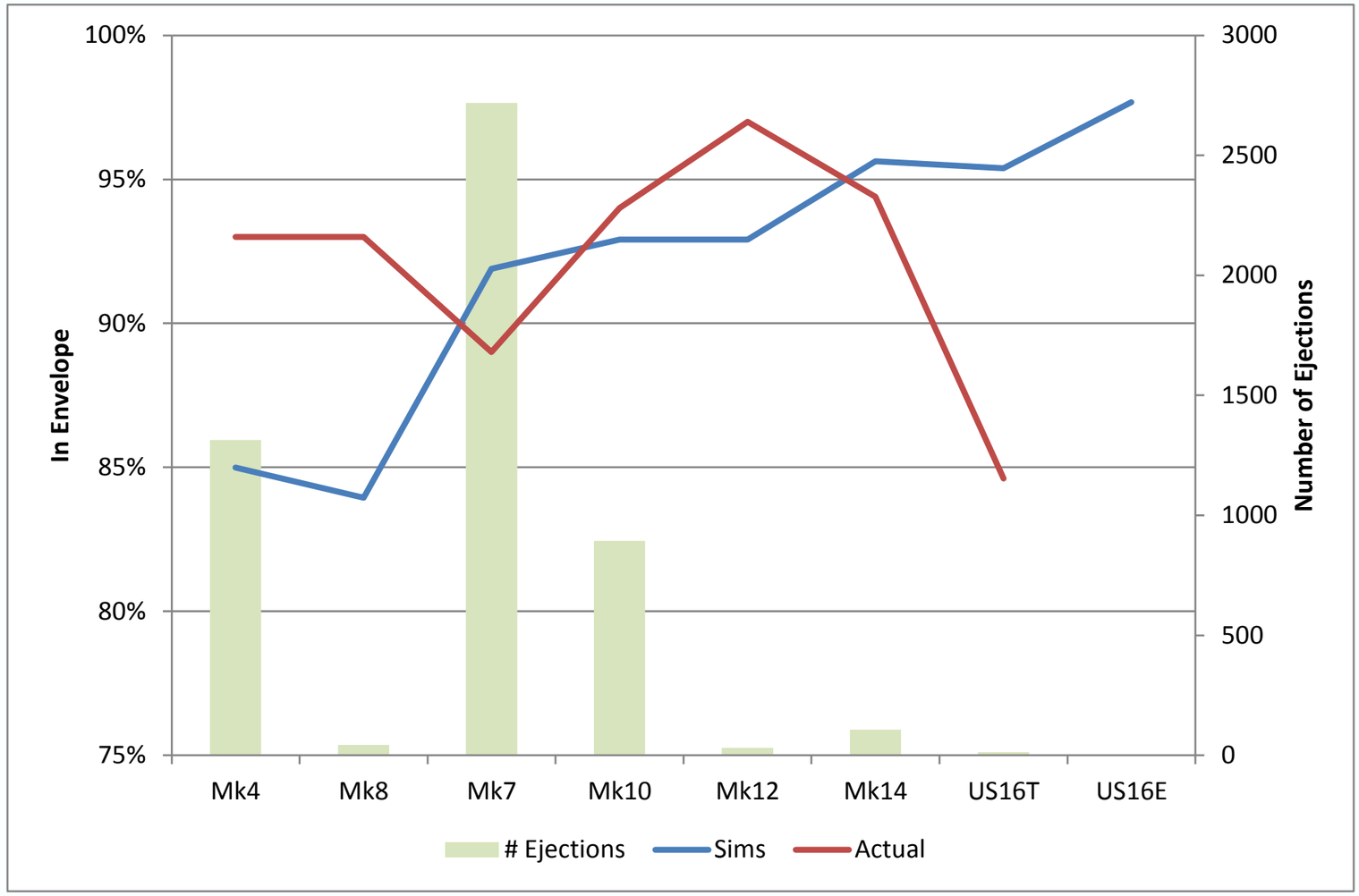


Predictions versus Actuals

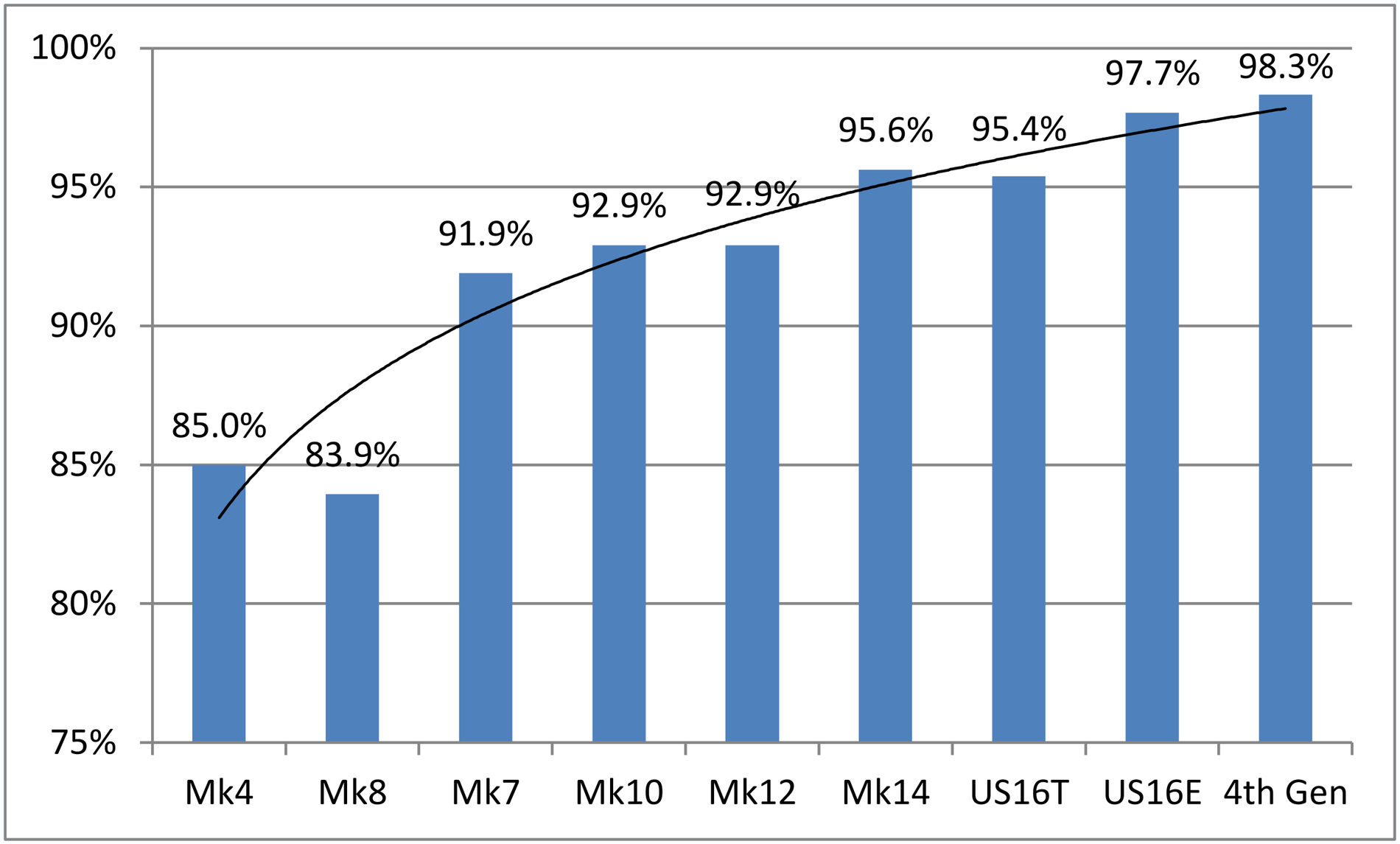


- Reasons for actuals differing from predictions
  - Ballistic sims include cases outside envelope, e.g. 0/0
  - 16T – only 13 ejections, 1 mishap OOE*, twin ejection

* OOE = Out Of Envelope

4th Gen

- Controllable propulsion, ground-avoiding guidance
- Achieves 98.3% versus 97.7% for latest Mk16



safe europe

Martin-Baker

Conclusions

- Latest seats seem not far off 4th Gen level of performance in terms of terrain clearance
  - But more work to be done to analyse remaining OOE cases – are they really “impossible”?
  - Might lead to a change of paradigm
- Database + simulation can be used to answer many questions
  - What difference does X make?