Chapter 3

STREAMER FOLDING TECHNIQUES (KAPLOW AND JONES)

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ABSTRACT

The purpose of this project was to test under controlled conditions the effect of different methods of folding streamers as used in NAR and FAI competition. Five identical streamers were made. The size of each streamer was 10 x 100 cm and each streamer weighed 13.0 grams, including the simulated model weight. Each streamer was folded in a different manner. One was folded over 1/3 of its length (Sykos); one folded over its full length (fully folded); one folded full length and curled (Bulgarian); one folded as to helix on its own (helix), and one folded in a zig-zag fashion (bowtie). They were then dropped several times each from the sixth floor of the Fermi National Accelerator Laboratoy atrium, a distance of 19.5 meters. The descent times were then statistically analyzed.

The results show that different methods of folding streamers do affect their sink rates, and, moreover, contradict previously published work. The fully folded streamer was found to be best, followed by the Bulgarian and Sykos methods tied for second and third. The helix was fourth best, and the bowtie method was the least efficient of all streamers tested. The helix streamer did consistently spiral in helix fashion, the only streamer to do so. It also dropped straighter, always landing on the floor directly below, and never getting caught in any of the nearby obstructions. Since these results contradict previous work, further research in this area is necessary.

3.1 Introduction

Early experiments in the area of streamer duration were done by Trip Barber and Tom Milkie [1], and by Chris Flanigan [2]. Their work consisted of drop tests on different streamer materials in an attempt to determine the best material for use in streamer duration. Further development was done by Charles Sykos [3], with the goal of producing better Class I streamer duration times for use at the 1980 World Championships. While Charlie was able to significantly improve the streamer duration performance, his work lacked the detail of the two MIT reports. We had come up with several modifications to streamer folding techniques that we wanted to test. As a result, we chose to build a set of identical streamers using 5 different methods to fold them. They were then dropped and timed to see what effects the different methods of folding would have on their sink rates.

3.2 Apparatus and Procedure

Five streamers were cut from a roll of Hunt Bienfang #107 light yellow drafting tissue. All were 10 x 100 cm (4 x 40 inches), and weighed 3.5 grams. Each streamer was taped via the side attachment method to a 28cm length of shock line, which in turn was taped to 3 pennies glued together with Hot Stuff. The three pennies were chosen as a test weight because they are relatively consistent in weight (about 3 grams each), cheap and easy to obtain, and close to the weight of a typical mini-engine streamer duration model with an empty engine casing. The string-tape-penny assemblies weighed 9.5 grams each. The total weight of each streamer used in the tests, as dropped, was 13.0 grams. Small bits of clay were to be used to make each streamer weigh the same, but they all turned out identical within the accuracy of the Ohaus balance (0.1 gram).

Each streamer was folded by rolling the portion to be folded (the full length in all but one case) around a piece of 3/8" diameter rod, withdrawing the rod and flattening and creasing the resulting roll. The roll was then unwound, and each crease was individually folded into the streamer. The reverse folds were then put in, one at a time, in the opposite direction. Five different folds were tried:

1. Straight-across folds of the type that are now common ("fully folded").

2. Folds for 1/3 of the streamer length, the rest being left unfolded ("Sykos

method").[1]

3. Folds along the full length, and also curled, as was done to the streamers used by the Bulgarian team at the 1980 World Championships ("Bulgarian method").

4. Reverse folds angling across the streamer in the same direction, resulting in a streamer that will form a helix in its relaxed state ("helix").

5. Reverse folds alternating in each direction, resulting in a streamer that zig-zagged along both sides ("bowtie").

The streamers were dropped over the edge of the staircase of the sixth floor of the atrium building at the Fermi National Accelerator Laboratory, 19.5 meters from the floor below. Models were timed by two timers, as per NAR standards, with the two times then averaged into a single data point. Failure of either timer caused the other time to be used as the data point. In one instance both times were lost, as shown in the data table. Each streamer was to be dropped 20 times. Recovery and other operational problems results in slightly fewer than this number of drops for each streamer, and not all streamers had the same number of "qualified flights."

An indoor location was chosen to eliminate the effects of wind, thermals, etc. from the test results. Unfortunately, this facility was still not ideal. Several areas of the floor were at different elevations, and there were trees in the bottom of the atrium, resulting in several data points being corrected or thrown out completely.

Further problems were encountered in timing. In standard NAR competition, one is used to starting the watch when the model begins to move directly in front of the timer. In this case, the model was directly overhead and it was not always clear exactly when the streamer was released. Various techniques were tried to visually alert the timers to the release, with varying degrees of success.

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[1] The Sykos report actually indicated that 2/3 of the streamer should be folded - ed

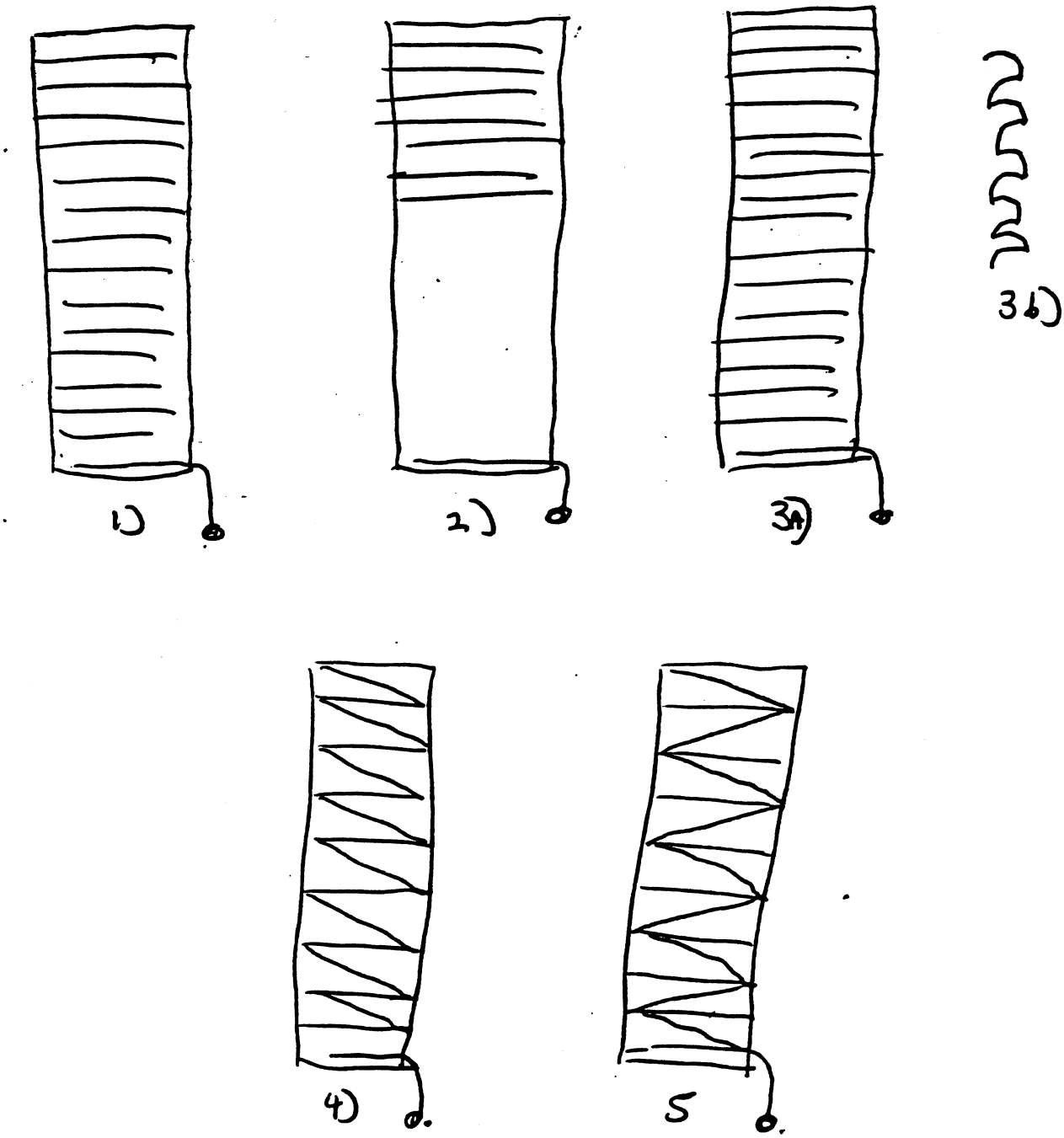

Figure 3-1. Streamer Folding Techniques

3.3 Data

Tables 3-1 through 3-5 show the raw timing data from the drop tests. An asterisk shows a data point which was dropped from the statistical computation; the reason is indicated. Notations concerning small negative distances indicate when the streamer did not reach the reference ground level due to landing on an obstruction. [Note: due to their volume, all data tables have been collected at the end of the narrative text - ed.]

3.4 Analysis of Data

Several corrections had to be made to the collected data. Those tests where the streamer went through the trees or actually became caught in the trees were thrown out. Those tests that simply grazed the trees were left in, but the condition was noted in the data. Due to the flower beds, several models did not reach the floor that was used as the reference point for measurements. Those tests received an adjusted time of:

$$T' = (H T) / (H - \Delta H)$$

where T is the measured time, H is the reference height (19.5m), and ΔH is the distance that the streamer fell short of reaching the floor. T' is then the resulting corrected time. This corrected time is such that the computed sink rate for the shortened distance agrees with the computed sink rate for the corrected time. The data was re-analyzed using the corrected data. No differences in the results were noted when the corrected and the original uncorrected data were compared. Tables 3-6 through 3-10 show the corrected data as described above.

The data as collected, corrected and reduced using two Fortran programs written by the authors is summarized in Tables 3-11 and 3-12. Also shown are sink rates in meters per second (and feet per second) for comparison to the tests done by the MIT Rocket Society [1] and [2]. Please note when comparing this data to the MIT data that both the streamer sizes and model masses are different. As a result, direct comparisons between the two are not possible. Computations of sink rate assume that the streamer rapidly reached terminal velocity, and then continued for the rest of its drop at that velocity. Observation of the drop tests showed this to be a valid assumption. As a result the sink rate can simply be calculated by:

sink rate = height (m) / time (s)

3.5 Conclusions

There is no significant difference between the raw and the corrected data. There is a difference shown in the technique used in folding the streamer. Except for the Bulgarian and Sykos methods, which are statistically indistinguishable, there is a significant difference between any other pair of folding methods. Of the five folding methods tested, the fully folded, uncurled streamers produced the best results. This contradicts previous work in this area, and as a result more tests are planned in the future. The scope of this project was limited to the 10 x 100 cm Hunt Bienfang #107 streamer typically used in class A streamer duration. It is still not known what effect different sizes and materials would have on the sink rates of the streamers that are folded with different techniques.

The streamers in this test were dropped already deployed, thus the problems noted in Sykos's report [3] causing him to only partially fold the streamer would not have shown up in our work. It should be noted that, as a result of these tests, the authors have been using "fully folded" streamers except that the last 5 cm are left unfolded and are wrapped around the streamer for convenience and improved reliability in deployment as suggested by Sykos. He noted in his report that there was no consistent procedure in any of the tests. Model mass, streamer size, streamer material, engine type, and streamer folding technique all varied through the testing. The best flights were near the end, when some materials had been discarded, lighter vehicles may have been used, and hotter engines were available. Given the amount of data presented there, there is no way of telling exactly what caused the times to increase, but they clearly did. This may explain some of the differences in results for fully folded vs partially folded streamers between Sykos's testing and the results presented in this report.

Aside from the duration of each streamer, qualitative properties of the helix streamer were noted. The helix folding technique did cause the streamer to spiral, whereas not all of the other streamers did this reliably. Furthermore, the helix streamer was found to not veer off course in its descent. Helix streamers always landed in the target area, never over any of the planted areas of the atrium. This might be useful in the recovery of high altitude models or for spot landing. Wind would still be a factor, but random streamer

drift seems to be minimized. The main disadvantage, aside from the non-optimum duration times, is the difficulty of packing such a streamer into a tube. [In its folded state, the helix streamer is a flat 4-inch circle! -ed.]

3.6 Acknowledgements

The authors wish to thank the staff of Fermi National Laboratory for the use of their facility, particularly the security and fire departments, who went out of their way to allow us to perform our experiments. Further thanks go to Mark Bundick, who literally went out on a ledge dropping the streamers from the sixth floor. Thanks also go to the Schmitt family for providing timing assistance and retrieving streamers from six floors below. Stop watches were provided by Mark Bundick, Bob Kaplow and Mark Schmitt. Mark Bundick provided an Ohaus triple beam balance to weigh the streamers and weights.

Computer time was available both on Bob Kaplow's home system, a very small PDP-11 running RT-11, as well as on a larger PDP-11 running RSX-11M-PLUS and a VAX 11/780 running VMS at Digital Equipment Corp., Arlington Heights, IL. These systems were used both for data analysis and word processing in generating the report.

Materials for this project were already available to the authors. Approximate values are as follows:

1 roll Hunt Bienfang #107 light yellow paper	$5.00
1 roll 3/4" masking tape	1.00
1 roll of pennies used for weights	0.50
12# test braided nylon fishing line	1.00
trim clay (not used)	0.50

TOTAL COST	$8.00

3.7 Data Tables

Table 3-1. Raw Data: Fully folded streamer, 13.0 gm

7.500		6.850	-1.00m
7.800		8.000	
*4.600	streamer tangled	7.700	
7.000	glanced tree	7.900	
7.425		7.200	-1.00m
6.450	-.33m	7.750	
6.800		7.750	glanced tree
8.050		7.900	
7.300		7.600	
6.600	glanced tree		

N = 18 Arithmetic Mean = 7.42083 Standard Deviation = 0.485075
Error= 0.117649 0.99% Bounds: Lower= 7.11730 Upper = 7.72437
Minimum Value = 6.45000 Maximum Value= 8.05000 Range = 1.60000
Geometric Mean= 7.40453 Harmonic Mean= 7.38779 RMS = 7.43667

Table 3-2. Raw Data: Fully folded and curled (Bulgarian) streamer, 13.0 gm

6.500		6.950	
6.000		6.800	
5.800		6.800	
6.300	glanced tree	6.150	barrel roll
6.300		6.650	
6.950	off course	6.800	-.5m
6.550		5.550	-1.00m
5.950	barrel roll	6.450	
6.600		6.500	traveled
7.050			

N = 19 Arithmetic Mean = 6.45526 Standard Deviation = 0.405512
Error= 0.0955796 0.99% Bounds: Lower= 6.20867 Upper = 6.70186
Minimum Value = 5.55000 Maximum Value= 7.05000 Range = 1.50000
Geometric Mean= 6.44218 Harmonic Mean= 6.42875 RMS = 6.46799

Table 3-3. Raw Data: 1/3 folded (Sykos) 10 x 100 cm streamer, 13.0 gm

5.700		6.400	
6.600		6.750	
*5.100	timers not ready	6.900	
6.800		6.300	barrel roll, glanced tree
6.600		*6.900	through tree
5.550		6.700	
5.900		6.900	
6.250		6.150	-1.00m
6.500	glanced tree	*5.250	caught in tree
6.750			

N = 16 Arithmetic Mean = 6.42188 Standard Deviation = 0.405799
Error= 0.104777 0.99% Bounds: Lower= 6.15155 Upper = 6.69220
Minimum Value = 5.55000 Maximum Value= 6.90000 Range = 1.35000
Geometric Mean= 6.40858 Harmonic Mean= 6.39480 RMS = 6.43468

Table 3-4. Raw Data: Fully folded Helix 10 x 100 cm streamer, 13.0 gm

5.600		5.350	slight timing error
5.500		5.750	
5.200		5.750	
5.100		5.700	
5.650		5.500	
5.550		5.750	
5.300		6.150	
5.700		5.800	
5.450		5.900	
5.800			

N = 19 Arithmetic Mean = 5.60526 Standard Deviation = 0.248081
Error= 0.0584741 0.99% Bounds: Lower= 5.45440 Upper = 5.75613
Minimum Value = 5.10000 Maximum Value= 6.15000 Range = 1.05000
Geometric Mean= 5.59974 Harmonic Mean= 5.59419 RMS = 5.61075

Table 3-5. Raw Data: Fully folded Bowtie 10 x 100 cm streamer, 13.0 gm

*1.000	timers not ready	*5.450	through tree
4.000		4.550	-1.00m
4.500		4.650	
4.500		5.050	
4.300		5.050	
4.600	off course	4.250	
4.900		4.600	
4.550		4.800	
4.350		4.300	
4.100			

N = 17 Arithmetic Mean = 4.53235 Standard Deviation = 0.293031
Error= 0.0732571 0.99% Bounds: Lower= 4.34335 Upper = 4.72136
Minimum Value = 4.00000 Maximum Value= 5.05000 Range = 1.05000
Geometric Mean= 4.52990 Harmonic Mean= 4.51348 RMS = 4.54182

Table 3-6. Corrected Data: Fully folded 10 x 100 cm streamer, 13.0 gm

7.500		7.220	corr from 6.85 -1.00m
7.800		8.000	
*4.600	streamer tangled	7.700	
7.000	glanced tree	7.900	
7.425		7.590	corr from 7.2 -1.00m
6.560	corr from 6.45 -.33m	7.750	
6.800		7.750	glanced tree
8.050		7.900	
7.300		7.600	
6.600	glanced tree		

N = 18 Arithmetic Mean = 7.46917 Standard Deviation = 0.452518
Error= 0.109752 0.99% Bounds: Lower= 7.18601 Upper = 7.75233
Minimum Value = 6.56000 Maximum Value= 8.05000 Range = 1.49000
Geometric Mean= 7.45500 Harmonic Mean= 7.44037 RMS = 7.48286

Table 3-7. Corrected Data: Folded and curled (Bulgarian) streamer, 13.0 gm

6.500		6.950	
6.000		6.800	
5.800		6.800	
6.300	glanced tree	6.150	barrel roll
6.300		6.650	
6.950	off course	6.980	corr from 6.8 -.50m
6.550		5.850	corr from 5.55 -1.00m
5.950	barrel roll	6.450	
6.600		6.500	traveled
7.050			

N = 19 Arithmetic Mean = 6.48053 Standard Deviation = 0.384959
Error= 0.0907347 0.99% Bounds: Lower= 6.24643 Upper = 6.71462
Minimum Value = 5.80000 Maximum Value= 7.05000 Range = 1.25000
Geometric Mean= 6.46894 Harmonic Mean= 6.45722 RMS = 6.49195

Table 3-8. Corrected Data: 1/3 folded (Sykos) streamer, 13.0 gm

5.700		6.400	
6.600		6.750	
*5.100	timer not ready	6.900	
6.800		6.300	barrel roll, glanced tree
6.600		*7.150	corr from 6.9, dropped
5.550		6.700	
5.900		6.900	
6.250		6.150	corr from 6.15 -1.00m
6.500	glanced tree	*5.250	caught in tree
6.750			

N = 16 Arithmetic Mean = 6.44250 Standard Deviation = 0.399799
Error= 0.103228 0.99% Bounds: Lower= 6.17617 Upper = 6.70883
Minimum Value = 5.55000 Maximum Value= 6.90000 Range = 1.35000
Geometric Mean= 6.42955 Harmonic Mean= 6.41604 RMS = 6.45489

Table 3-9. Corrected Data: Fully folded Helix streamer, 13.0 gm

5.600		5.350	slight timing error
5.500		5.750	
5.200		5.750	
5.100		5.700	
5.650		5.500	
5.550		5.750	
5.300		6.150	
5.700		5.800	
5.450		5.900	
5.800			

N = 19 Arithmetic Mean = 5.60526 Standard Deviation = 0.248081
Error= 0.0584741 0.99% Bounds: Lower= 5.45440 Upper = 5.75613
Minimum Value = 5.10000 Maximum Value= 6.15000 Range = 1.05000
Geometric Mean= 5.59974 Harmonic Mean= 5.59419 RMS = 5.61075

Table 3-10. Corrected Data: Fully folded Bowtie streamer, 13.0 gm

*1.000	timers not ready	*5.450	through tree
4.000		4.800	corr from 4.55 -1.00m
4.500		4.650	
4.500		5.050	
4.300		5.050	
4.600	off course	4.250	
4.900		4.600	
4.550		4.800	
4.350		4.300	
4.100			

N = 17 Arithmetic Mean = 4.54706 Standard Deviation = 0.299739
Error= 0.0749356 0.99% Bounds: Lower= 4.35372 Upper = 4.74039
Minimum Value = 4.00000 Maximum Value= 5.05000 Range = 1.05000
Geometric Mean= 4.53716 Harmonic Mean= 4.52724 RMS = 4.55693

Table 3-11. Raw Data Summary

C = 0.99% Z = 2.580

Group	N	Mean	SD	m/s	(f/s)	Streamer
1	18	7.42083	0.485075	2.63	8.62	Fully folded
2	19	6.45526	0.405512	3.02	9.91	Bulgarian
3	16	6.42188	0.405799	3.04	9.96	Sykos
4	19	5.60526	0.248081	3.48	11.41	Helix
5	17	4.53235	0.293031	4.30	14.11	Bowtie

Correlation for 5 groups, 10 pairings:

Groups	Dsig	Crit	Dmean	V	T	Signif. Diff.
1 2	.1474	.3803	.9656	35	6.578	YES
1 3	.1529	.3944	.9990	32	6.465	YES
2 3	.1376	.3551	.03338	33	.2423	NO
1 4	.1277	.3295	1.816	35	14.44	YES
2 4	.1091	.2814	.8500	36	7.794	YES
3 4	.1163	.3001	.8166	33	7.301	YES
1 5	.1346	.3473	2.888	33	21.15	YES
2 5	.1171	.3020	1.923	34	16.13	YES
3 5	.1239	.3196	1.890	31	15.39	YES
4 5	.09105	.2349	1.073	34	11.89	YES

Table 3-12. Corrected Data Summary

C = 0.99% Z = 2.580

Group	N	Mean	SD	m/s	(f/s)	Streamer
1	18	7.46917	0.452518	2.61	8.56	Fully folded
2	19	6.48053	0.384959	3.01	9.87	Bulgarian
3	16	6.44250	0.399799	3.03	9.93	Sykos
4	19	5.60526	0.248081	3.48	11.41	Helix
5	17	4.54706	0.299739	4.29	14.07	Bowtie

Correlation for 5 groups, 10 pairings:

Groups	Dsig	Crit	Dmean	V	T	Signif. Diff.
1 2	.1385	.3573	.9886	35	7.166	YES
1 3	.1462	.3771	1.027	32	6.971	YES
2 3	.1334	.3441	.03803	33	.2858	NO
1 4	.1209	.3119	1.864	35	15.64	YES
2 4	.1051	.2711	.8753	36	8.331	YES
3 4	.1150	.2967	.8372	33	7.562	YES
1 5	.1291	.3330	2.922	33	22.36	YES
2 5	.1144	.2951	1.933	34	16.67	YES
3 5	.1236	.3189	1.895	31	15.46	YES
4 5	.09233	.2382	1.058	34	11.58	YES

3.8 References

[1] Barber, Trip and Milkie, Tom.
Streamer Duration Optimization.
Journal of the MIT Rocket Society :19-26, November, 1972.

[2] Flanigan, Chris.
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