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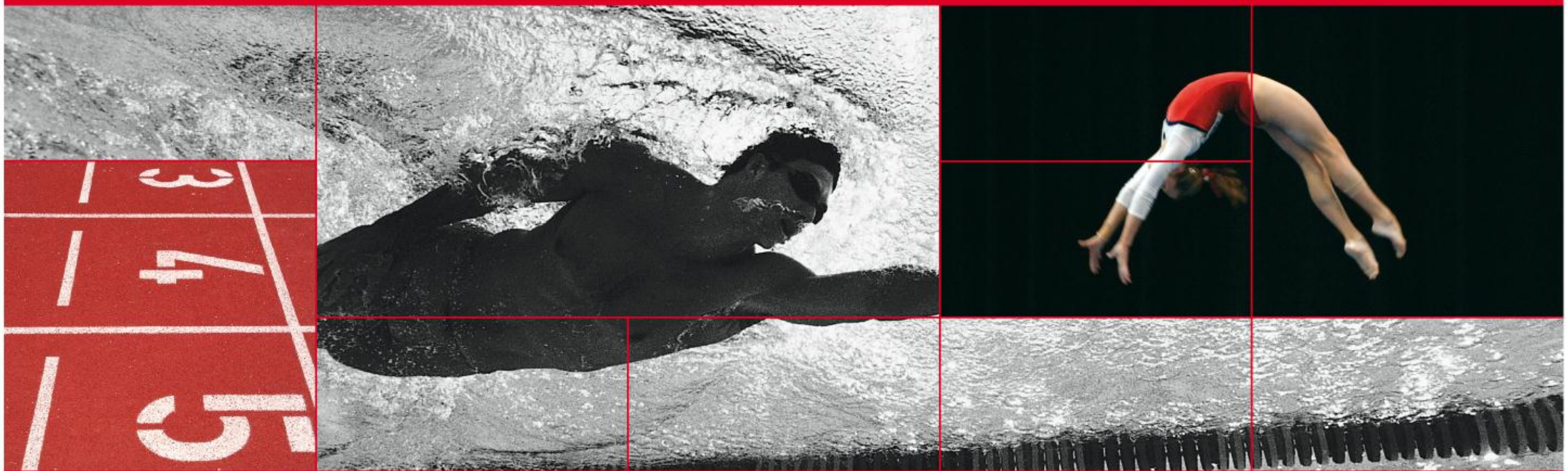
Evaluation and Feedback in Swimming
Historical Overview

Bruce Mason
Australian Institute of Sport

Hong Kong Sports Institute – Invited Lecture – July 2011



www.ausport.gov.au

Introduction

Å Aquatic Biomechanics has difficulty obtaining good objective and quantifiable data.

Å Problem to obtain quality kinematic analysis. (poor image resolution – splashes & bubbles)

Å Problem to obtain quality Kinetic analysis. (unable to use force transducers)

Å Therefore servicing & feedback often relied upon underwater video & subjective evaluation.

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The Early 1970’s

Å Lift Versus Drag propulsion.

Å Lift Propulsion theory dominated at this time.

Å A biomechanist in servicing would identify and encourage lateral movement of the hand in support of lift propulsion being dominant.

Å This was an era in which swim flumes were evolving that would assist in the servicing and feedback to swimmers.

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Mid 1970’s to Mid 1980’s

- Active Drag and Propulsion was evaluated.
- Intra Stroke Velocity variation was evaluated using video.
- Better video techniques evolved. (combined above/below water image of swimmer)
- Competition race analysis evolved. (Rein Haljand from Estonia)

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The Wave Trough

- Alex Popov 1.8m/s

- Alex Popov 2.1m/s

- Alex Popov 2.5m/s

Mid 1980's to Early 1990's

- Linear Accelerometry to investigate and reduce intra stroke velocity fluctuations.
- Starts and Turns investigated with video.
- MAD system for active drag analysis evolved.
- Large race analysis systems evolved (Canada, Australia & Japan). Emphasis on race plans.

Video Start and Turn Analysis in a training environment

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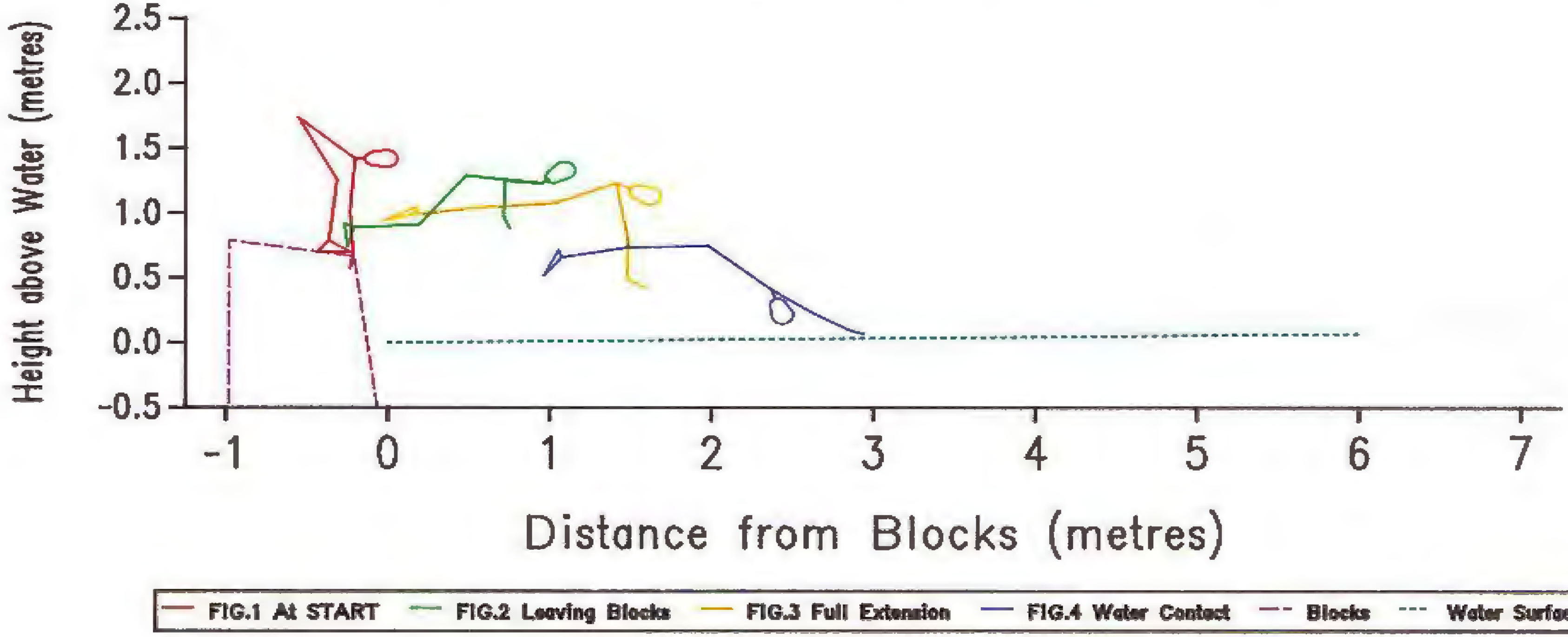
07OCT93___TRIAL#Q1___N_STOEL

Left_Blocks_at_0.72sec___Hit_Water_at_1.04sec_=_2.94metres



Biomechanical Analysis - Swim Starts

Trunk_Angle__Fig1=-42__Fig2=-7__Fig3=22__Fig4=-41_degrees

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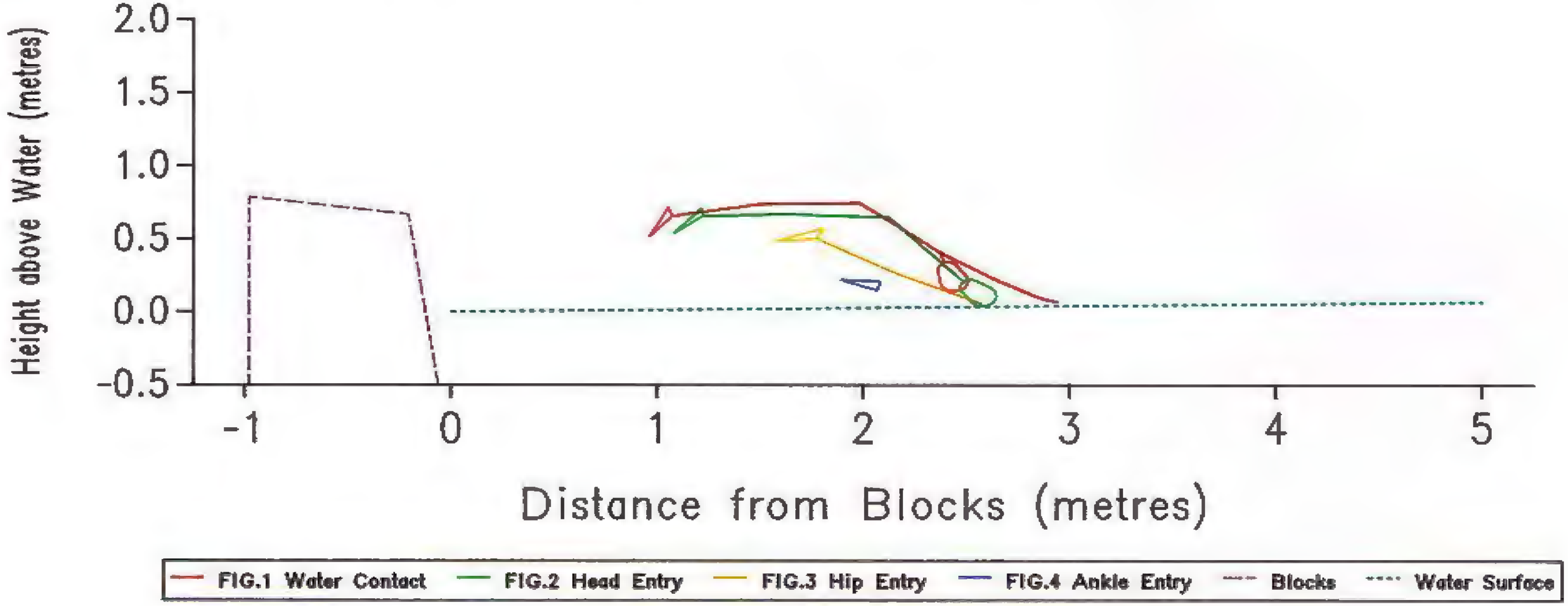
Left_Blocks_at_0.72sec___Hit_Water_at_1.04sec_=_2.94metres



Biomechanical Analysis - Swim Starts

Trunk_Angle-Head_Entry=-50_deg___Fing-Ank_Entry_Disp=88_cms

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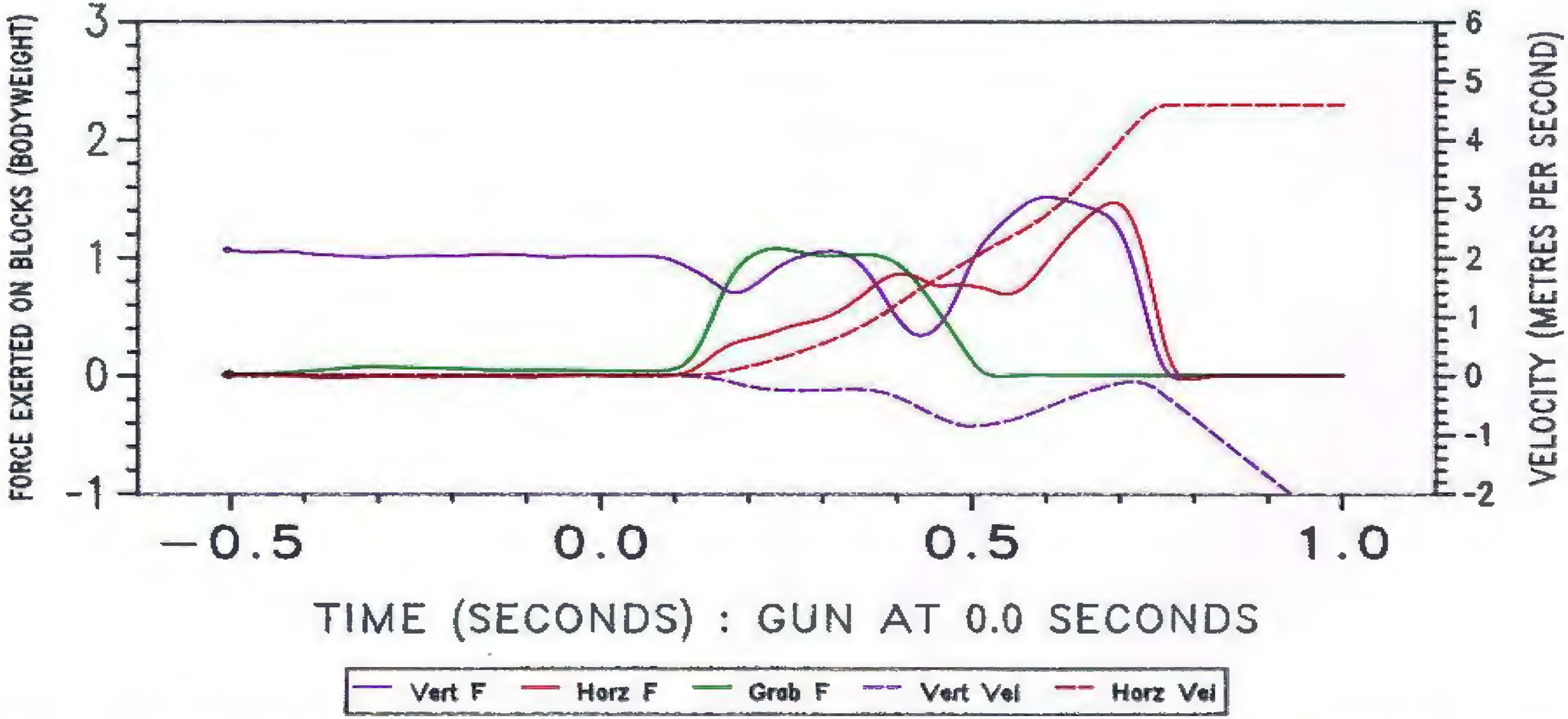
SWIMMING STARTS - FORCE PLATE ANALYSIS

START_25MAR97_KLIMM_K1



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Biomechanical Start Block Analysis

Athlete ID = Michael KLIM Freestyle k1

Reason = AIS

Date = 25 March 1997

Register	Value		Name
1	-0.43	(m/s)	Vertical Velocity at Takeoff
2	4.59	(m/s)	Horizontal Velocity at Takeoff
3	0.77	(sec)	Time on Blocks: Gun to Takeoff
4	-5.36	(deg)	Dive Angle at moment of Takeoff
5	5.94	(m/s/s)	Average Acceleration on Block

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The MAD Active Drag Analysis System

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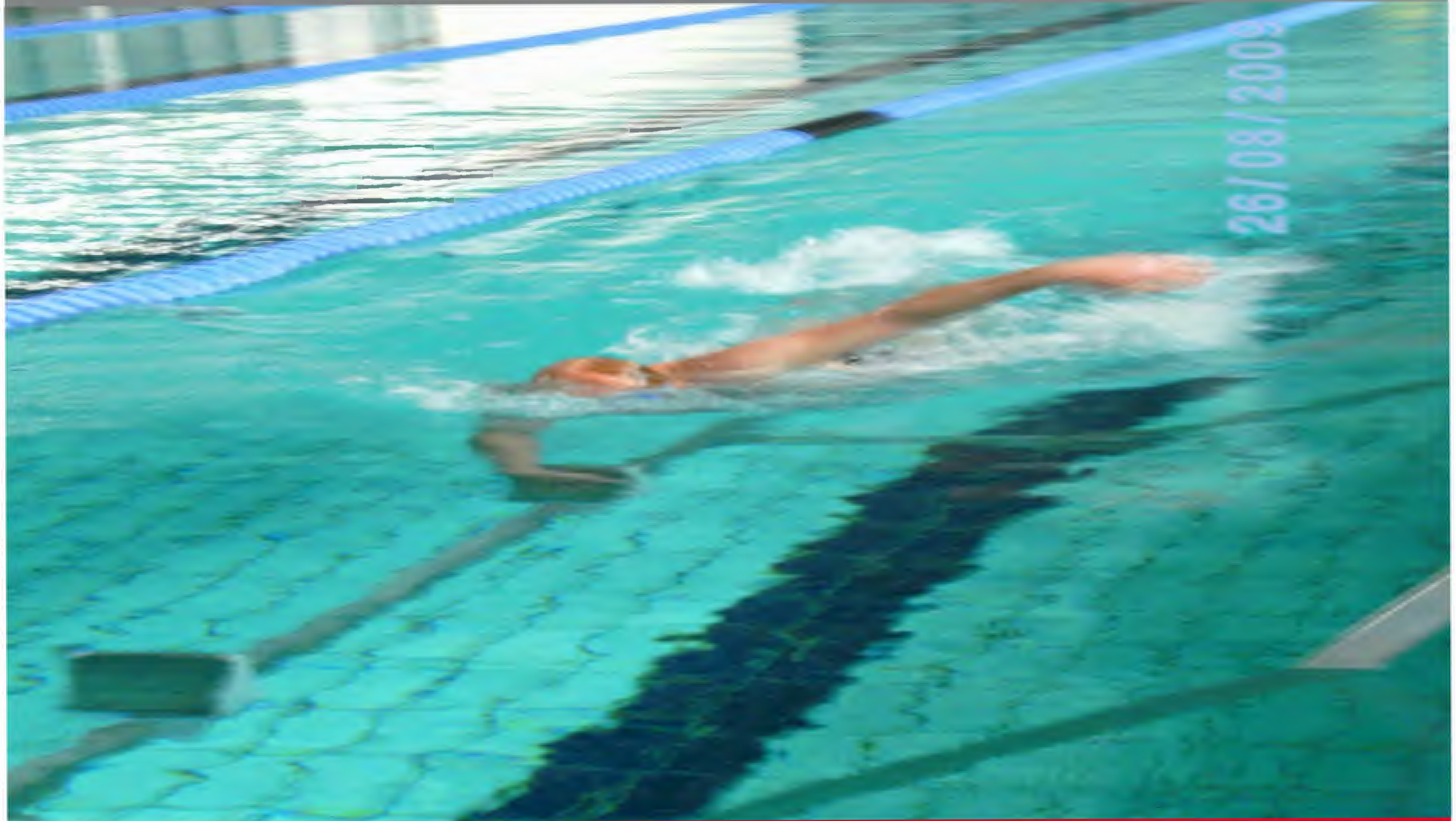

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Large Competition Race Analysis System

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BIOMECHANICS - COMPETITION ANALYSIS IN SWIMMING

Date = 3rd May 2000 Official Timing by OMEGA
Competition Meet = Australian Olympic Trials - Sydney - 2000
Swimmer = Alex POPOV State = Russia Club = AIS
Style = Free Style Age/Open = Open Gender = Mens
Distance = 100 metres
Event : A Final Lane Number : 5
Time of Swim = 0:49.87 Min:Sec Finish Place in A Final = 1st-EQ
Computer File for Data Storage = popova_m100fre_afinal_23apr00.CMP

LAP # 1
FIRST 25 METRES
Start time-Gun to 15m out= 6.00 sec
Stroke Length = 2.45 metres
Stroke Frequency = 48.4 Strokes/Min
= 1.240 sec/stroke
Interval Velocity= 1.97 metres/sec
Int INDEX SL*vel = 4.82 metres*metres/sec
Progressive 25m Split = 11.07 sec
Time for this 25m Split = 11.07 sec

Start Analysis
Off Block
0.760sec

(Vel= 2.50m/s)
(Vel= 1.97m/s)
(Vel= 2.26m/s)

LAST 25 METRES
Stroke Length = 2.84 metres
Stroke Frequency = 39.5 Strokes/Min
= 1.520 sec/stroke
Interval Velocity= 1.87 metres/sec (Vel= 1.87m/s)
Int INDEX SL*vel = 5.29 metres*metres/sec
Progressive 50m lap time = 24.68 sec
Time for this 50m lap = 24.68 sec (Vel= 2.03m/s)
Time for this 25m Split = 13.61 sec (Vel= 1.84m/s)

LAP # 2
FIRST 25 METRES
Turn time 7.5m to 7.5m = 7.40 sec (Vel= 2.03m/s)
Stroke Length = 2.68 metres
Stroke Frequency = 43.5 Strokes/Min
= 1.380 sec/stroke
Interval Velocity= 1.94 metres/sec (Vel= 1.94m/s)
Int INDEX SL*vel = 5.19 metres*metres/sec
Progressive 25m Split = 36.87 sec
Time for this 25m Split = 12.19 sec (Vel= 2.05m/s)

Turn Analysis
IN = 4.23sec
OUT= 3.17sec
IN/(IN+OUT)= 57.2%

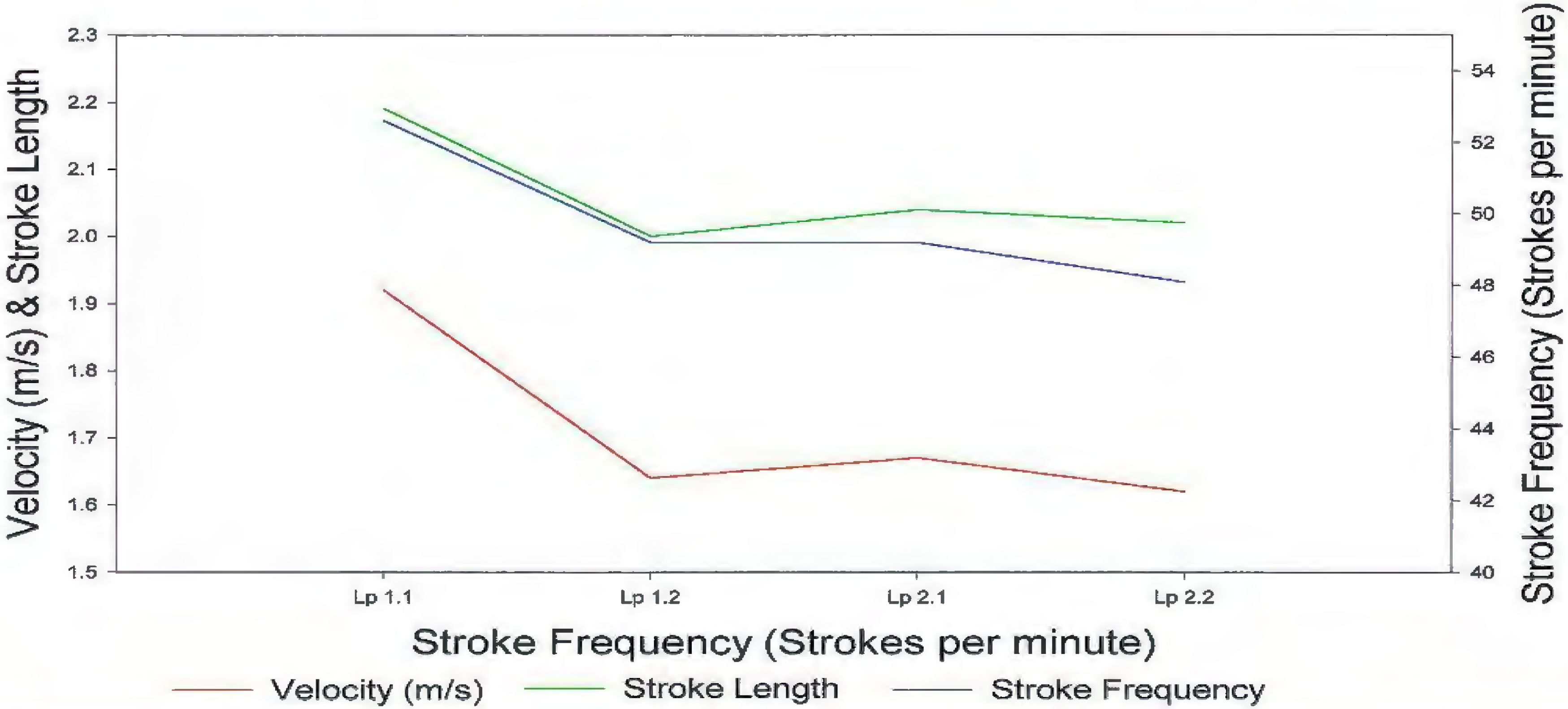
LAST 25 METRES
Stroke Length = 2.64 metres
Stroke Frequency = 42.9 Strokes/Min
= 1.400 sec/stroke
Interval Velocity= 1.89 metres/sec (Vel= 1.89m/s)
Int INDEX SL*vel = 4.97 metres*metres/sec
Finish Time (from 5m out)= 2.39 sec (Vel= 1.88m/s)
Progressive 50m lap time = 49.87 sec
Time for this 50m lap = 25.19 sec (Vel= 1.98m/s)
Time for this 25m Split = 13.00 sec (Vel= 1.92m/s)

Australian Olympic Trials	Sydney-AUSTRALIA	May-2000	Pg 1 of 1
A Final	BIOMECHANICAL ANALYSIS	Australian Format	Official Timing by OMEGA
100 metres Backstroke	Open Mens 15th May 2000	A.I.S. Biomechanical Analysis for Australian Swimming	

	Matt WELSH	*Josh WATSON*	*Ray HASS*	*Ross POWELLS*	*Robert WYLLIE*	*Robert VAN DER ZANT*	*Cameron DELANEY*	*Adrian RADLEY*
	Victoria	N.S.W.	Victoria	Queensland	West.Aust.	Queensland	N.S.W.	Victoria
Lane #	4	5	6	3	1	2	7	8
25m Lap#	1	1	1	1	1	1	1	1
StartTime15m	6.33	6.42	7.10	6.93	6.89	7.17	7.14	6.78
StrkeLeng(m)	2.01	1.96	2.19	2.17	2.09	2.06	2.19	2.09
StkFreq(S/m)	55.6	54.5	51.7	50.0	53.6	51.7	52.6	51.7
Velocty(m/s)	1.86	1.79	1.89	1.81	1.86	1.78	1.92	1.80
Index(m*m/s)	3.75	3.51	4.13	3.92	3.88	3.66	4.22	3.75
25m Split(s)	11.70	12.02	12.40	12.46	12.26	12.80	12.34	12.34
50m Lap#	1	1	1	1	1	1	1	1
StrkeLeng(m)	1.99	1.97	2.03	2.16	2.01	2.13	2.00	2.01
StkFreq(S/m)	52.9	52.2	52.1	48.4	50.3	48.1	49.2	50.7
Velocty(m/s)	1.76	1.71	1.77	1.74	1.68	1.71	1.64	1.69
Index(m*m/s)	3.51	3.38	3.59	3.77	3.39	3.64	3.29	3.40
25m Split(s)	14.37	14.62	14.41	14.55	14.82	14.70	15.21	14.80
Lap Time(s)	26.07	26.64	26.81	27.01	27.08	27.50	27.55	27.14
25m Lap#	2	2	2	2	2	2	2	2
TurnTm 7.5*2	7.28	7.36	7.88	7.72	7.64	7.96	8.12	7.60
StrkeLeng(m)	1.98	1.97	2.04	2.20	2.00	2.08	2.04	1.99
StkFreq(S/m)	51.1	51.7	49.6	45.5	50.4	47.5	49.2	50.0
Velocty(m/s)	1.68	1.70	1.68	1.67	1.68	1.65	1.67	1.66
Index(m*m/s)	3.33	3.34	3.43	3.67	3.38	3.43	3.41	3.30
25m Split(s)	13.25	13.26	13.77	13.69	13.60	14.10	14.03	13.68
50m Lap#	2	2	2	2	2	2	2	2
StrkeLeng(m)	1.96	1.88	1.99	2.13	1.95	2.04	2.02	2.00
StkFreq(S/m)	50.8	52.3	48.9	44.6	48.4	48.6	48.1	45.7
Velocty(m/s)	1.66	1.64	1.62	1.58	1.57	1.65	1.62	1.52
Index(m*m/s)	3.25	3.08	3.23	3.36	3.06	3.38	3.29	3.05
FinTime(5m)	2.77	2.72	2.92	2.93	3.04	2.91	2.94	3.08
25m Splt(s)	14.82	14.92	15.24	15.60	15.77	15.00	15.26	16.20
Lap Time(s)	28.07	28.18	29.01	29.29	29.37	29.10	29.29	29.88
Reslt(m:s.s)	0:54.14	0:54.82	0:55.82	0:56.30	0:56.45	0:56.60	0:56.84	0:57.02
Place	1st	2nd	3rd	4th	5th	6th	7th	8th
AvSwimVelcy	1.72	1.70	1.72	1.68	1.67	1.69	1.69	1.65
AvStrokeFreq	52.2	52.5	50.4	46.7	50.3	48.6	49.4	49.1
AvStrokeLeng	1.98	1.94	2.05	2.16	2.00	2.08	2.05	2.01
Av Index	3.42	3.30	3.52	3.64	3.36	3.51	3.47	3.32
StartTm(sec)	6.33	6.42	7.10	6.93	6.89	7.17	7.14	6.78
Turn Tm(adj)	7.28	7.36	7.88	7.72	7.64	7.96	8.12	7.60
Fin. Tm(adj)	2.77	2.72	2.92	2.93	3.04	2.91	2.94	3.08
Free Swim Tm	37.78	38.31	37.94	38.72	38.95	38.58	38.70	39.61
Accounted Tm	54.16	54.81	55.84	56.30	56.52	56.62	56.90	57.07

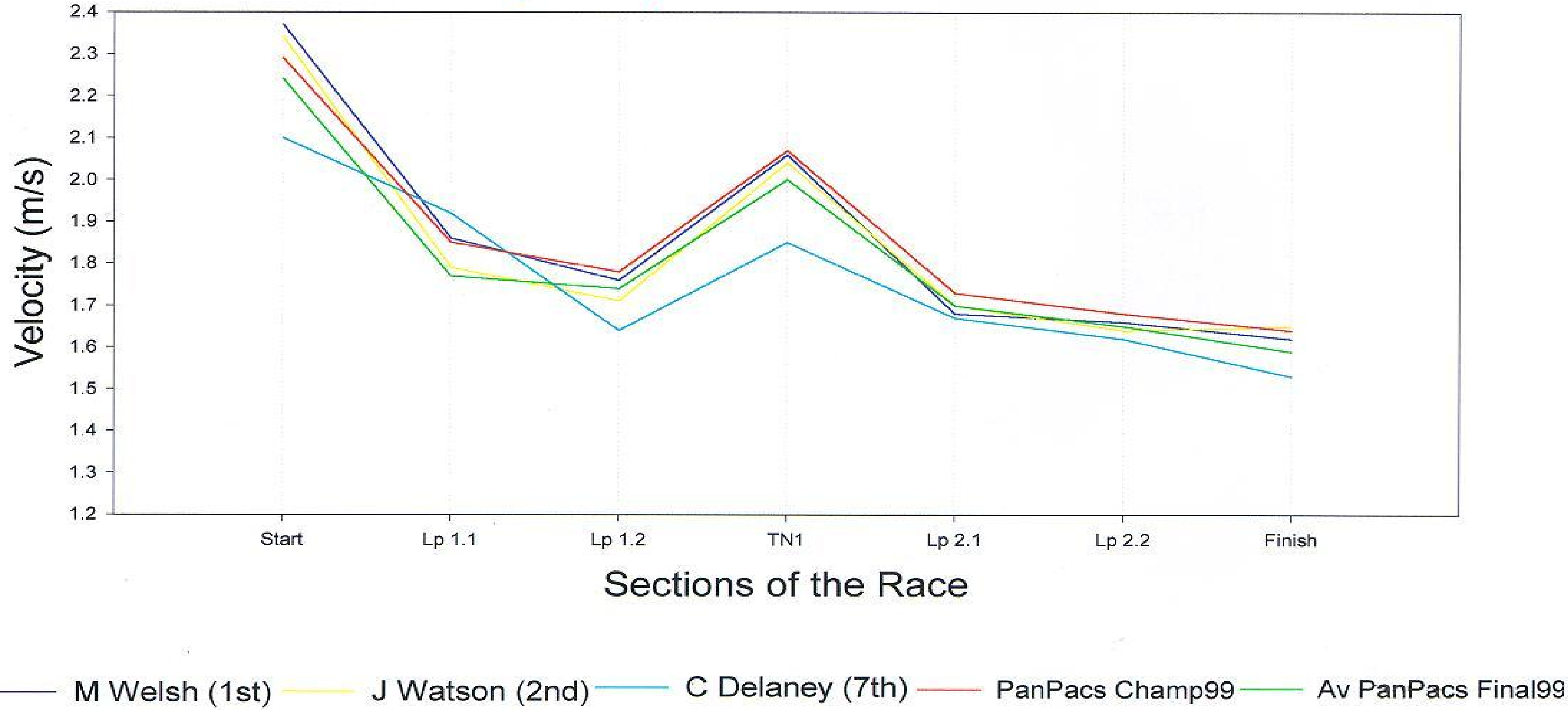
Australian Institute of Sport - Competition Swim Analysis
Australian Olympic Trials - May 2000

Mens Open 100m Backstroke - Final - Cameron DELANEY (7th)
Relationship Between Stroke Length/Frequency and Velocity



Australian Institute of Sport - Competition Analysis
Australian Olympic Trials - May 2000

Mens Open 100m Backstroke - Final - Cameron DELANEY (7th)
Velocity Comparison Between Swimmers



Early to mid 1990's

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Å Evaluation of Active Drag and Propulsion.

Å Competition Analysis provide additional information such as Stroke Lengths and Stroke Rates to refine race plans.

Å Portable race analysis systems evolved.

Å Refinement of Start and Turn Analysis systems in a training environment. More objective data.

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SWAN Portable Analysis System

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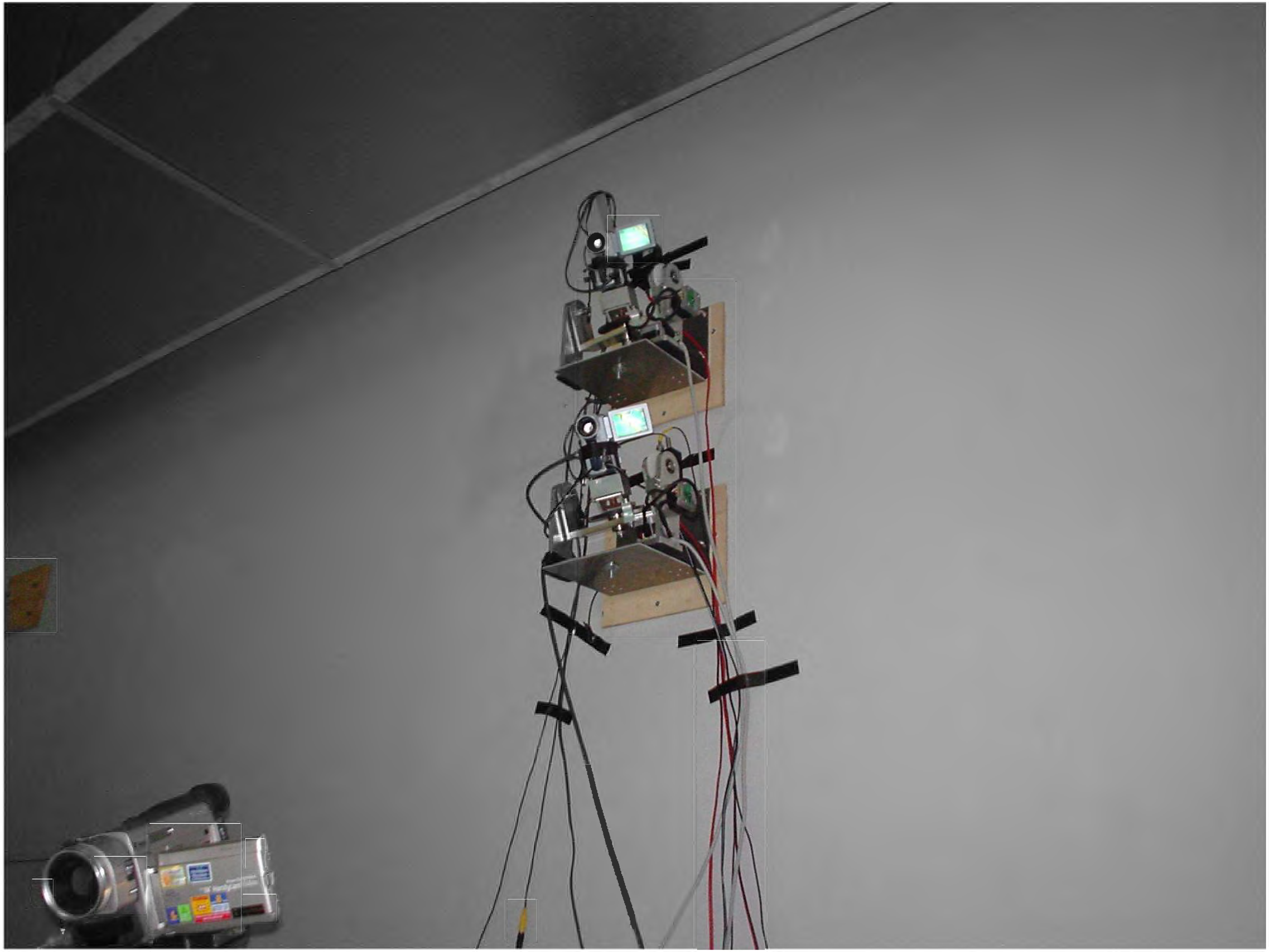
81
79
029



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Portable Competition Analysis System

Swan Portable Competition Analysis

Short Course Mens100m Backstroke WR

Swan Portable Competition Analysis

Long Course Womens 100m Freestyle WR

The Late 1990’s

Å Interactive Software to diagnose inefficiencies in swimmer’s technique.

Å Active and Passive Drag evaluated. VPM active drag analysis evolved. Pressure across hand.

Å Coordination of Swimming actions to investigate reduction of intra stroke velocity variations.

Å More sophisticated Start and Turn Analysis systems evolved.

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Pressure Across the Hand

Å Measuring Pressure Differences across the hand

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More Complex Start and Turn Analysis Systems Used

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SWAN Analysis System

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Swan Start Analysis

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BIOMECHANICS - START COMPARISON - FINAL REPORT

Ian THORPE 6/6/00 - Average of 2 trials
Olympic Orientation Camp - June 2000 - caloundra
Computer File for Data Storage = A:\OLYO2\ITFR02S.TXT

Phase	Event	Prog. Time	Interval Time	Prog. Distance	Interval Distance	Progr. Velocity	Interval Velocity
	Gun	0.00		0.01			
Initiation			0.88		1.93		2.20
	Leave Blocks	0.88		1.95		2.21	
Flight			0.34		1.99		5.94
	Entry	1.22		3.94		3.24	
Underwater			3.13		7.24		2.31
	Resurface	4.35		11.17		2.57	
Free Swim			2.09		3.83		1.84
	15m	6.43		15.00		2.33	

	Swimmer	Comparison	Comment
Total Time	6.43	6.95	much shorter than average
Initiation Interval Time	0.88	0.87	average
Flight Interval Time	0.34	0.58	much shorter than average
Underwater Interval Time	3.13	3.32	average
Dist at Entry	3.94	3.15	much further than average
Dist at Resurface	11.17	0.00	much further than average
Av Velocity Overall	2.33	2.16	much faster than average
Flight Velocity	5.94	3.03	much faster than average
Underwater Velocity	2.31	2.22	average
Free Swim Velocity	1.84	1.57	much faster than average
World Times Comparison			
Start Time to 15m	6.43	7.09	much shorter than average

Comparison file A:\COMPARE\MSTART.TXT
Combined Camp Data '98 - Men's 400m Fre Starts
Kowalski
Thorpe
Hackett

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SWAN Analysis System

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SWAN Turn Analysis Above Water

SWAN TURN analysis Below Water

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BIOMECHANICS - TURN COMPARISON - FINAL REPORT

Ian THORPE 6/6/00 - Average of 2 trials
Freestyle, Height 1.96 metres
Olympic Orientation Camp - June 2000
Computer File for Data Storage = A:\OLYO2\ITFR01T.TXT

Phase	Event	Prog. Time	Interval Time	Prog. Distance	Interval Distance	Progr. Velocity	Interval Velocity	Strokes
	7.5m	0.00		-7.50				
Pre Rotation			3.64		6.78		1.86	1.00
	Start Turn	3.64		-0.72		1.86		
Rotation			0.71		1.22		1.71	
	Touch Board	4.36		0.50		1.84		
Pushoff			0.41		1.46		3.56	
	Leave Board	4.76		1.96		1.99		
Underwater			2.91		6.04		2.08	
	Breakout	7.67		8.00		2.02		
Post Breakout			-0.20		-0.50			0.00
	7.5m	7.47		7.50		2.01		

In Turn Time	4.36		Pre Turn Swim Velocity	1.83
Out Turn Time	3.11		Post Turn Swim Velocity	1.74
In/(In+Out)%	58.3%			

	Swimmer	Comparison	Comment
Total Time	7.47	8.03	shorter than average
Rotation Interval Time	0.71	0.70	average
Pushoff Interval Time	0.41	0.40	average
Underwater Interval Time	2.91	1.96	much longer than average
Dist at Start of Turn	-0.72	-1.16	much less than average
Dist at Breakout	8.00	5.83	much further than average
Av Velocity Overall	2.01	1.88	faster than average
Pre Rotation Velocity	1.86	1.58	much faster than average
Pushoff Velocity	3.56	3.86	average
Underwater Velocity	2.08	2.00	faster than average
World Times Comparison			
In Turn Time	4.36	4.64	much shorter than average
Out Turn Time	3.11	3.46	much shorter than average
Overall Time	7.47	7.94	much shorter than average

Comparison file A:\COMPARE\MALETURN.TXT
Combined Camp Data - Men's 400 Fre Turns
Hackett
Kowalski
Thorpe

Late 1990's continued

- Breathing, body position and undulating movements examined with respect to swimming efficiency.
- Effect of body roll on arm movement and swimming speed.
- Examination of relationship between SL & SR.

  When does SL drop off in races.
- Evaluation of suits for particular swimmers & which suit was better in particular events.

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Early to Mid 2000's

- Starts and Turn analysis in reference to type of Start. Grab Start versus Track Start.
- Starts evaluated from Gun to 15m.
- Turns evaluated from 5m way in to contact to 10m way out.
- Instrumentation to monitor intra stroke Velocity variations.
- Effectiveness of suits for particular swimmers.
- Manual Kinematic Analysis of Swimming.

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Kinematic Analysis

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[3D swimming Model]

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Mid to Late 2000's

Å Investigation of suits for particular swimmers.

Å Speedo LZR using compression and reduced seams to out performed other suits in Beijing Olympics.

Å Other suit manufacturers used non porous materials to trap air for performance. Service providers worked with suit manufacturers.

Å Restrictions by FINA on suit manufacture.

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Working with Swim Suit Manufacturers

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Mid to Late 2000’s continued

Å New Technologies involved in monitoring swimmers – miniaturisation of pressure sensors, gyroscopes and accelerometers allowed for quicker analyses.

Å Faster computers allowed immediate processing.

Å Gig E cameras allowed higher speed better resolution images.

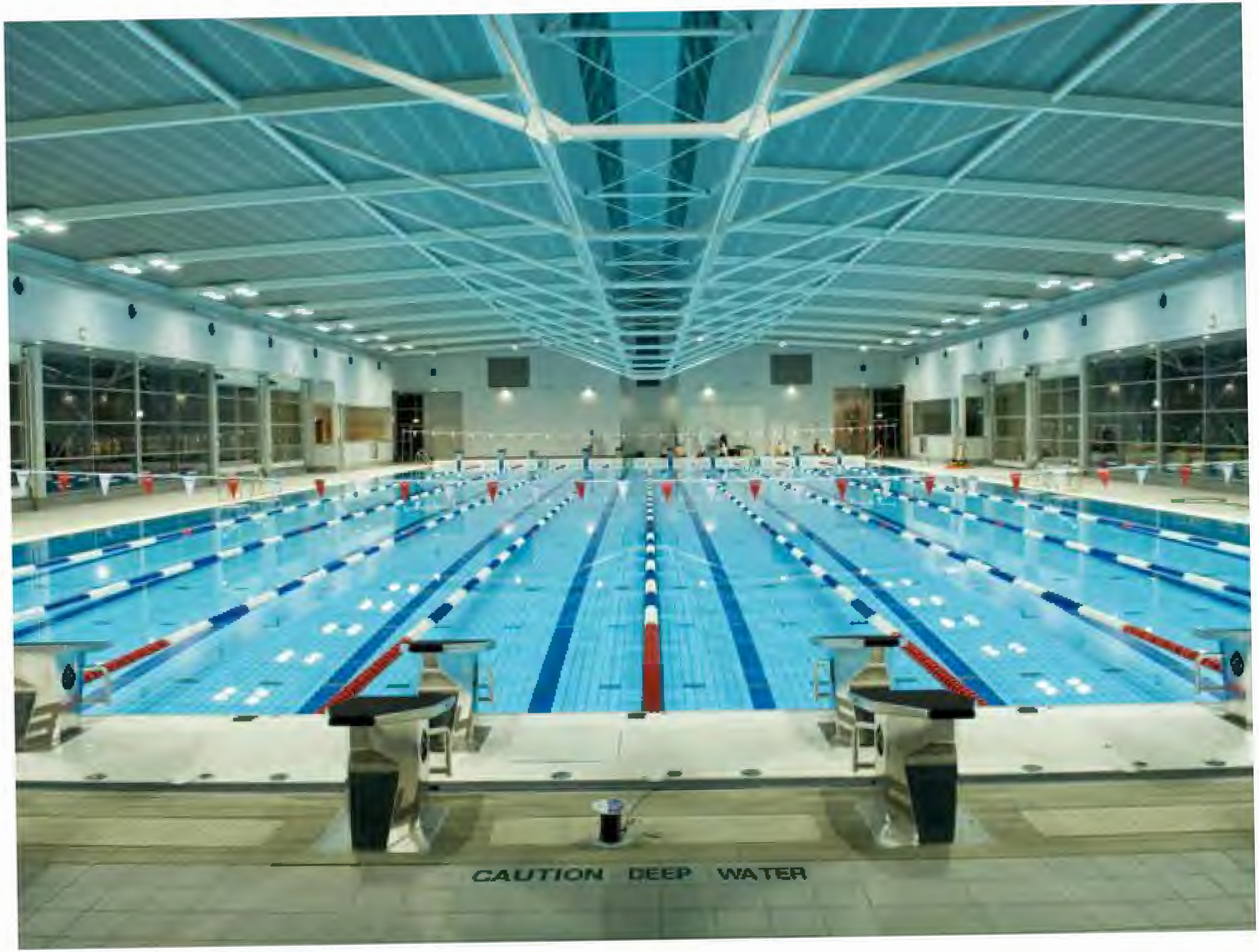
Å Analysis Systems developed that took advantage of the above.

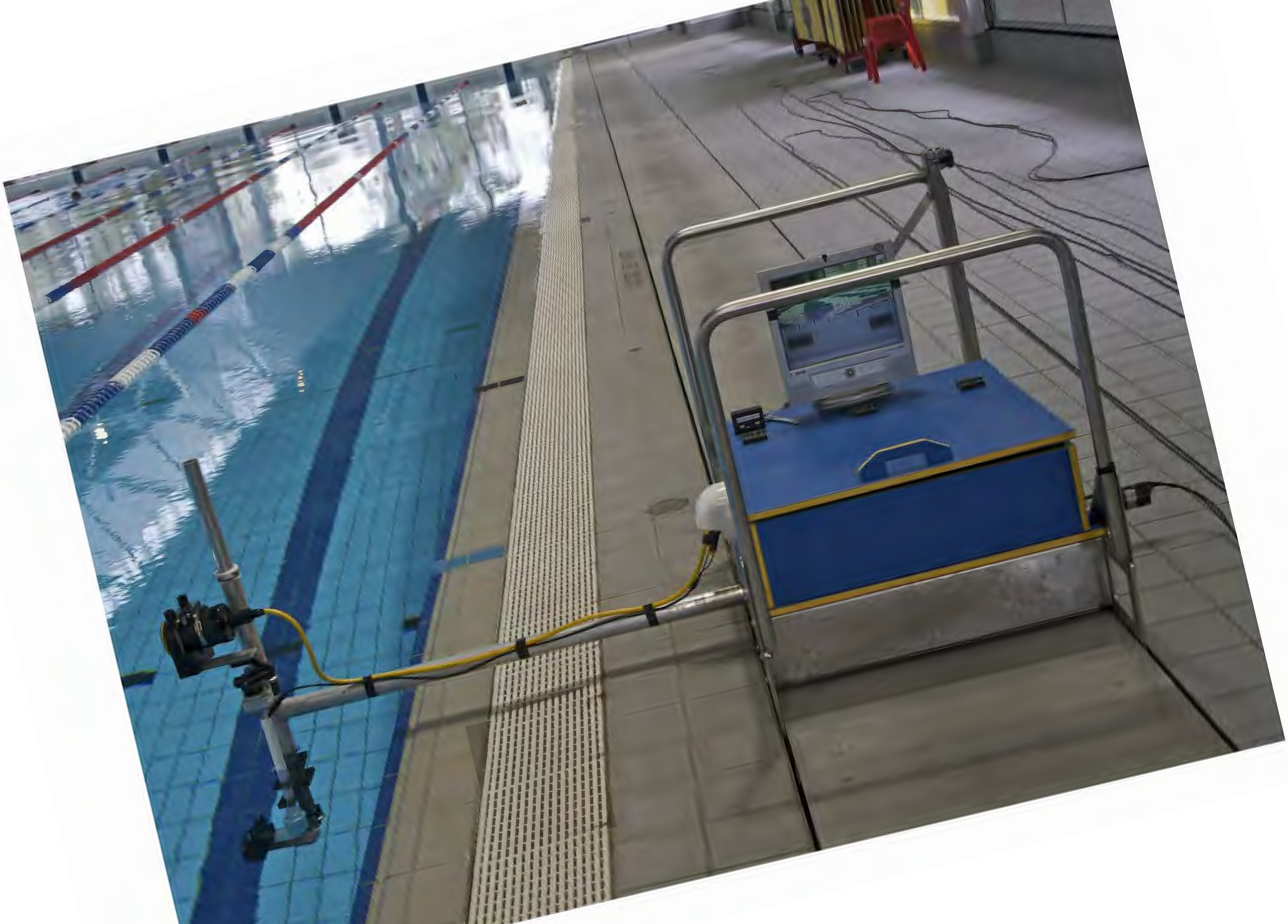
Å Competition analysis systems were automated.

Mid to Late 2000's continued

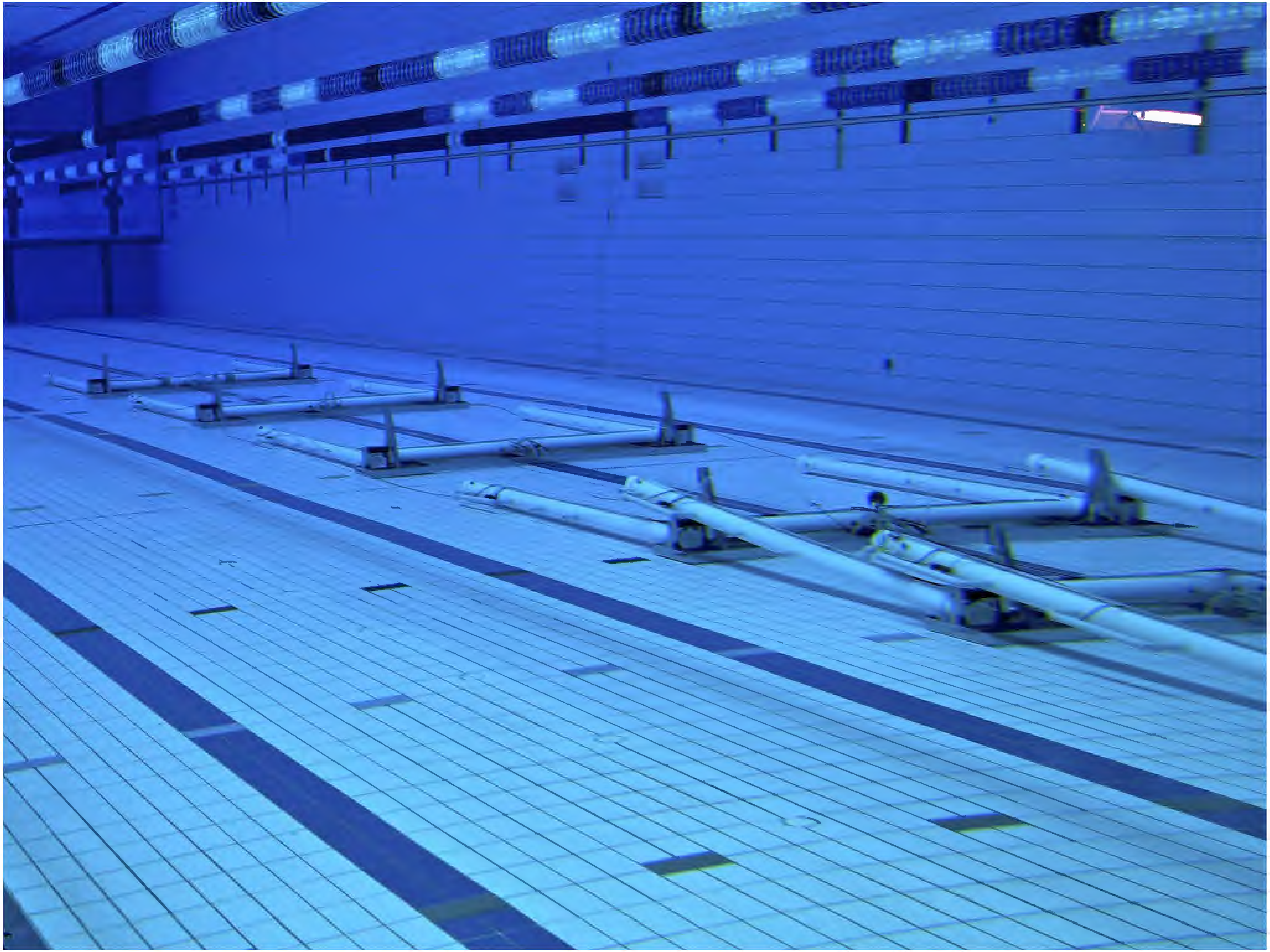
Å Development of new facilities for servicing of swimmers.

Å Development of new Equipment designed to service swimmers

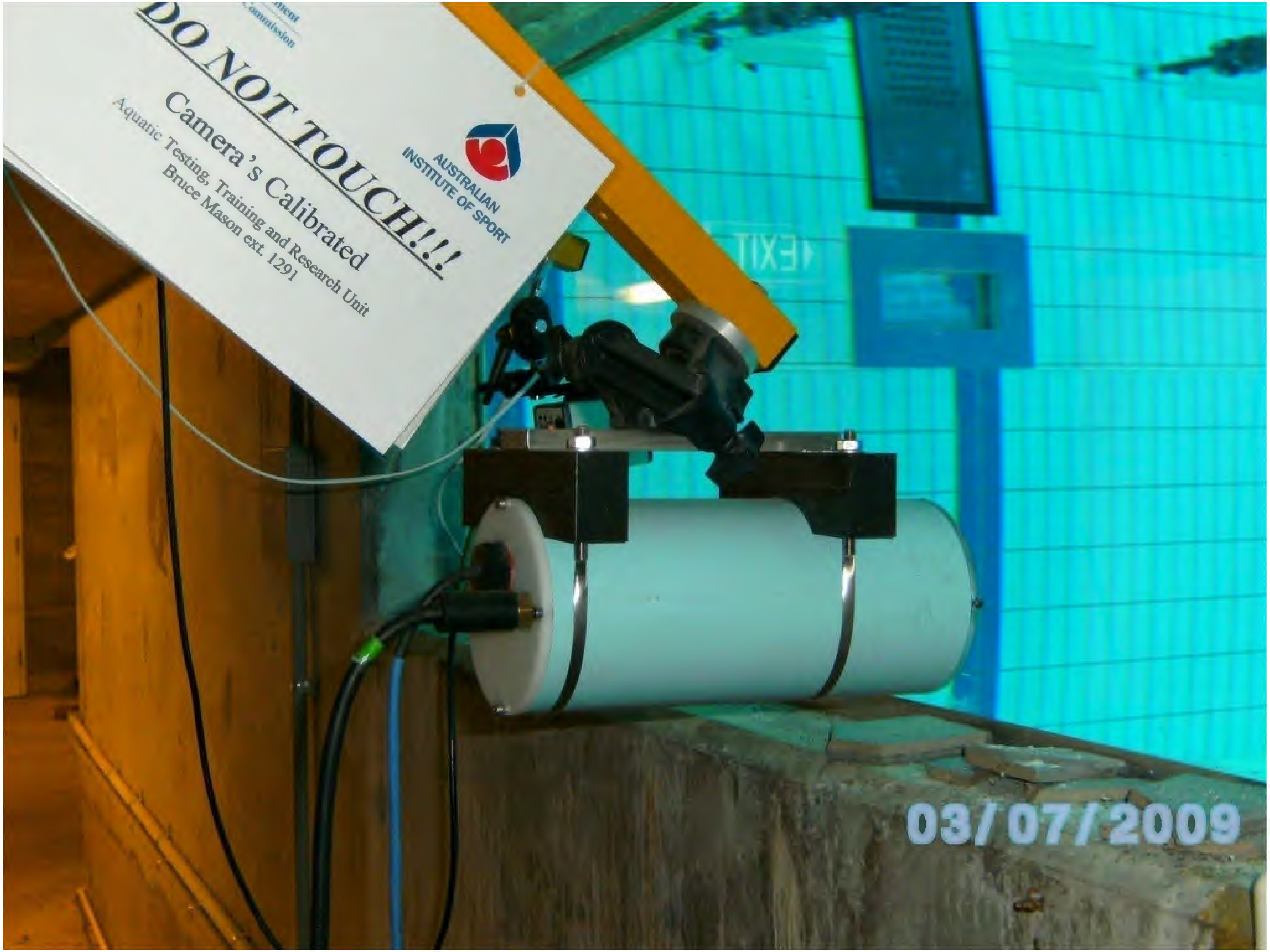

CAUTION DEEP WATER

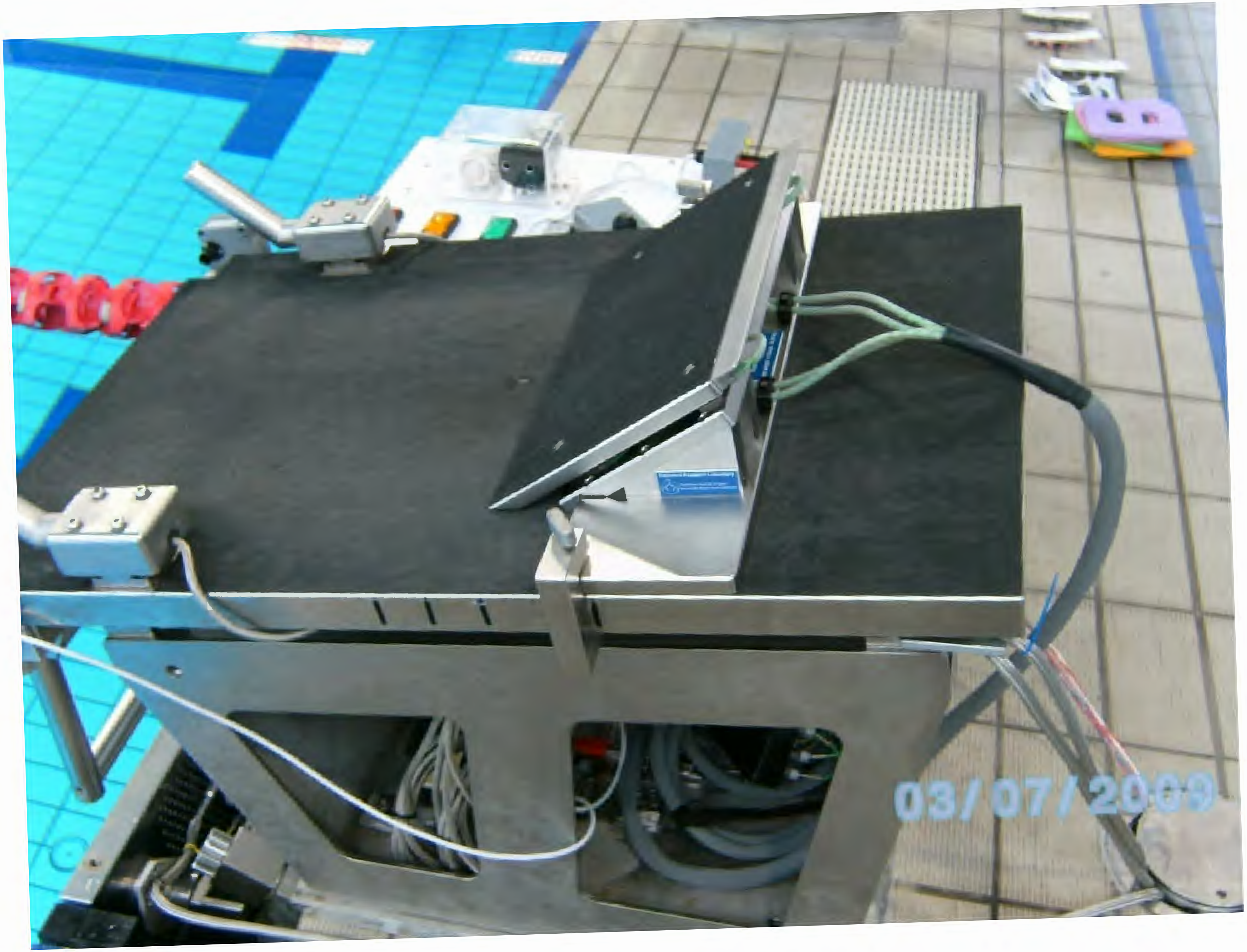



EXIT
24/ 06/ 2009




03/ 07/ 2009


DO NOT TOUCH!!!
Camera's Calibrated
Aquatic Testing, Training and Research Unit
Bruce Mason ext. 1291
AUSTRALIAN INSTITUTE OF SPORT
EXIT
03/07/2009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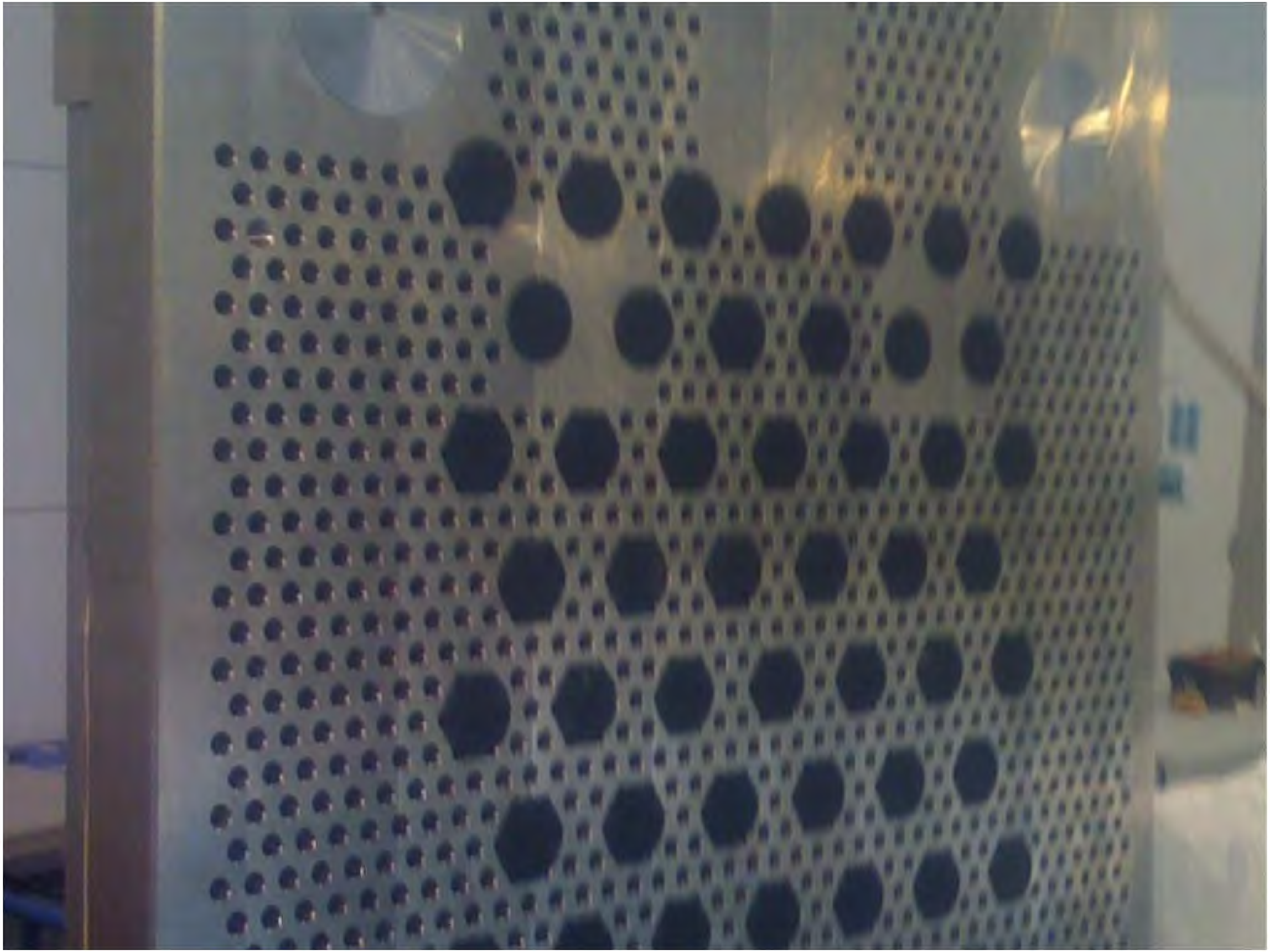


WetPlate

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2010 and Onwards

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- Look at flow characteristics around the swimmer. Tuffs on body, dye flow patterns & particle image velocimetry.
- Breathing in the stroke cycle.
- Use of new FINA starting block.
- Active Drag & the velocity profile of swimmers.
- More comprehensive Starts and Turns analysis systems.
- Computational Fluid Dynamics involved.

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Service to Acquaint Swimmer with new start block

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Active Drag and Propulsion


24/ 06/ 2009

Feedback on Propulsion

Brendon Rickard Breaststroke

Active Drag Analysis

Effective use of drag analysis as a servicing tool.
Swimmer reduces time over 400m Medley in Backstroke leg.

Tommy Fraser-Holmes July 2009 versus April 2010

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New Start & Turn Analysis Systems that utilise new Technology

WETPLATE Start & Turn Analysis

Demonstration of Programme

Wetplate Analysis Start – Cam.Prossor.

Effective Use of Grab Bar in starting not just a push off.

Higher Velocity off Block 4.22m/s v 3.83m/s
Greater Power output
Quicker to 15m by 0.4 sec

Start Analysis – Jessica Schipper.

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Effective Pull on Grab Bar to convert vertical force into horizontal force using body rotation.

Quicker off block 0.77s v 0.70s
Out slightly further to entry
Smaller entry hole

Start Analysis – Eamon Sullivan

Reduce size of entry hole in water following a start so as to retain high takeoff velocity.

Smaller entry hole 0.85m v 1.19m
Out slightly further to entry
Quicker to 15m 6.74s v 6.59s

Start Analysis – Cam Prossor.

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Reducing Entry Hole Size

Initiating a slight pike and flexion at knees

Wetplate Analysis Start – Bailey V Murphy.

Use of horizontal rather than upward movement of arms to allow body to get out of the water in Backstroke Starts.

Smaller entry hole 0.74m v 2.17m
Able to get further out of water

Backstroke Start Analysis – Belinda Hocking Versus Ash Delaney

Effective use of the Glide and Kick in Breaststroke starts.

Smaller entry hole 0.50m v 0.76m
15m time 8.19s v 8.24s
No extra kicks – Streamline and no extra kicks

Start Analysis – Tarnee White

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Grab versus Track Starting.

Same time off block

Velocity Grab=4.35m/s Track=4.24m/s

Distance Grab=2.99m Track=2.73

Dive Angle Grab=-4deg Track=-11deg

Start Analysis – Libby Trickett

Don’t commence underwater kicking too early in starts.

Same time off block
Same velocity off block
Entry further out 2.54m v 2.41m
Smaller entry hole 0.68m v 1.06m

Start Analysis – Alicia Coutts

Stay Relaxed prior to Start Signal in race starts.

Travels out further 2.91m v 2.79m
Delays first kick 7.17m v 7.06m
Lesser Dive angle -4deg v -11deg

Start Analysis – Alice Mills

Change from Grab to Track Starting to accommodate the new start blocks.

Quicker off block Grab=0.91s Track=0.81s
Higher Velocity off block Grab=4.47m/s Track=4.65m/s
Time to 15m Grab=7.92s Track=7.56s

[Start Analysis – Craig Calder]

Little time on wall with powerful leg drive is important in turns.

Less time on wall 0.21s v 0.26s
Less impulse off wall

Turn Analysis – Angie Bainbridge

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Use of the step-in rather than arm-swing in Relay Changeover.

Quicker off block 0.01s v 0.17s
Quicker into water by 0.13s
Slower velocity off block 4.74m/s v 4.46m/s

Relay Start Analysis – Matt Target.with Andrew Lautestein

Little time on wall with continuous push is important in turns.

Shorter time on Wall 0.27s v 0.32s
Less impulse off wall

Turn Analysis – Felicity Galvez

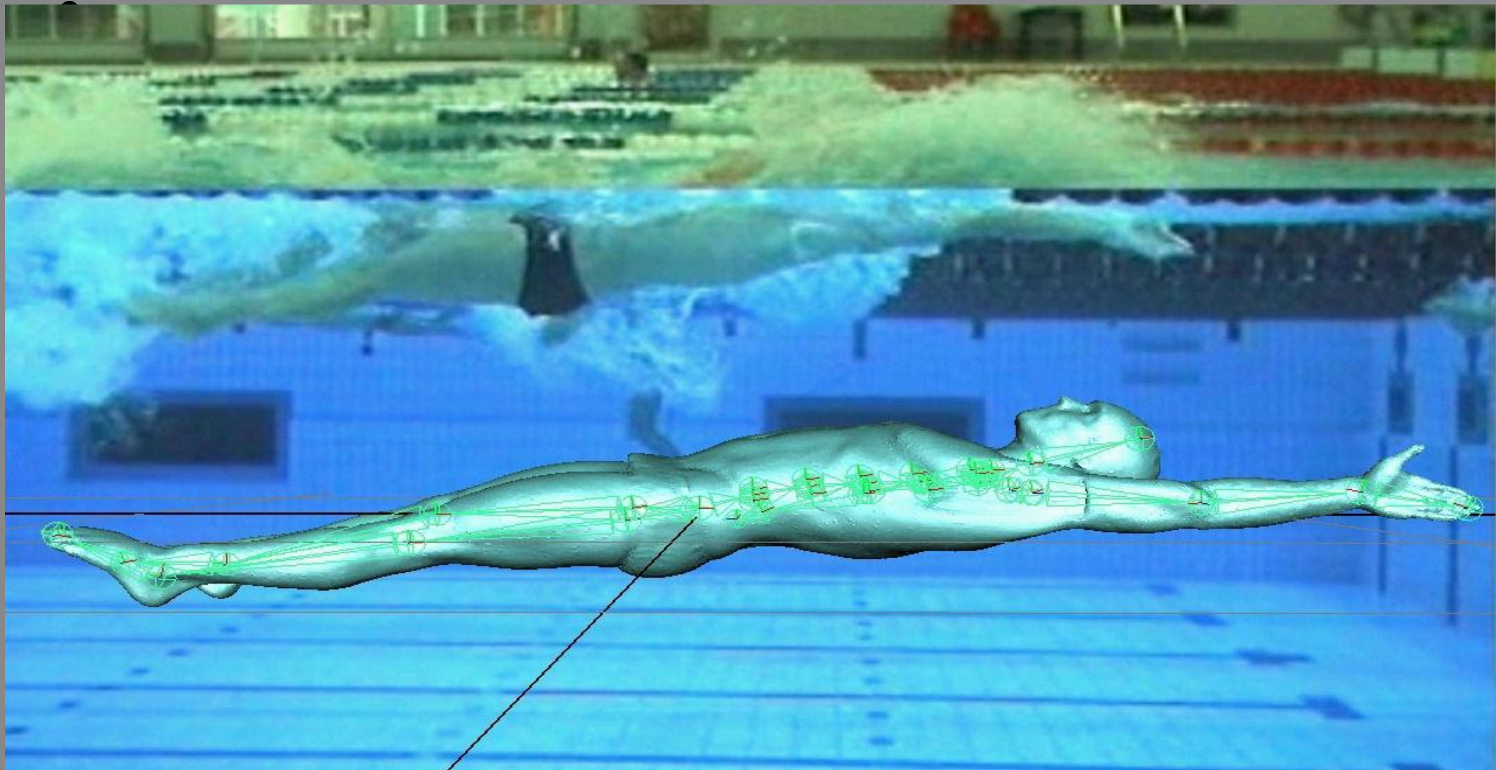
Important Aspects of the Fly to Back Turn In the Individual Medley

Miss time the wall
Less time on wall from Hand Touch to Feet off 1.19s v 1.42s
Greater impulse off wall 3.57m/s v 3.48m/s
Better turn time 9.11s v 9.49s

Turn Analysis – Alicia Coutts Versus   Stephanie Rice

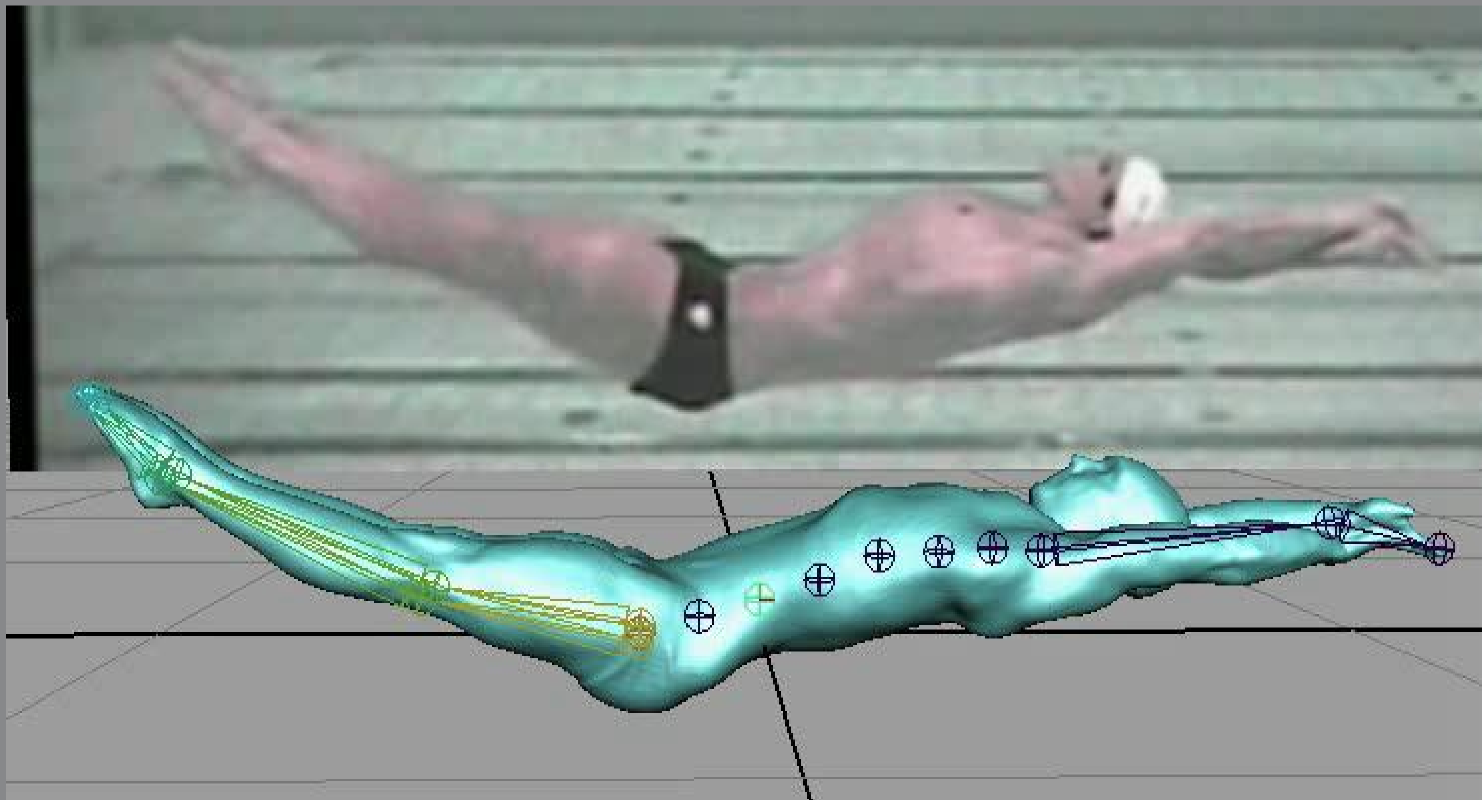
Improved backstroke animation

- Now have matching individual footage & laser scan



Submerged dolphin kick
Rigging and animating the surface mesh

- A single kicking period of footage was used as a reference for animating the surface mesh – side by side



A 3 stroke variants were subsequently made

Submerged dolphin kick

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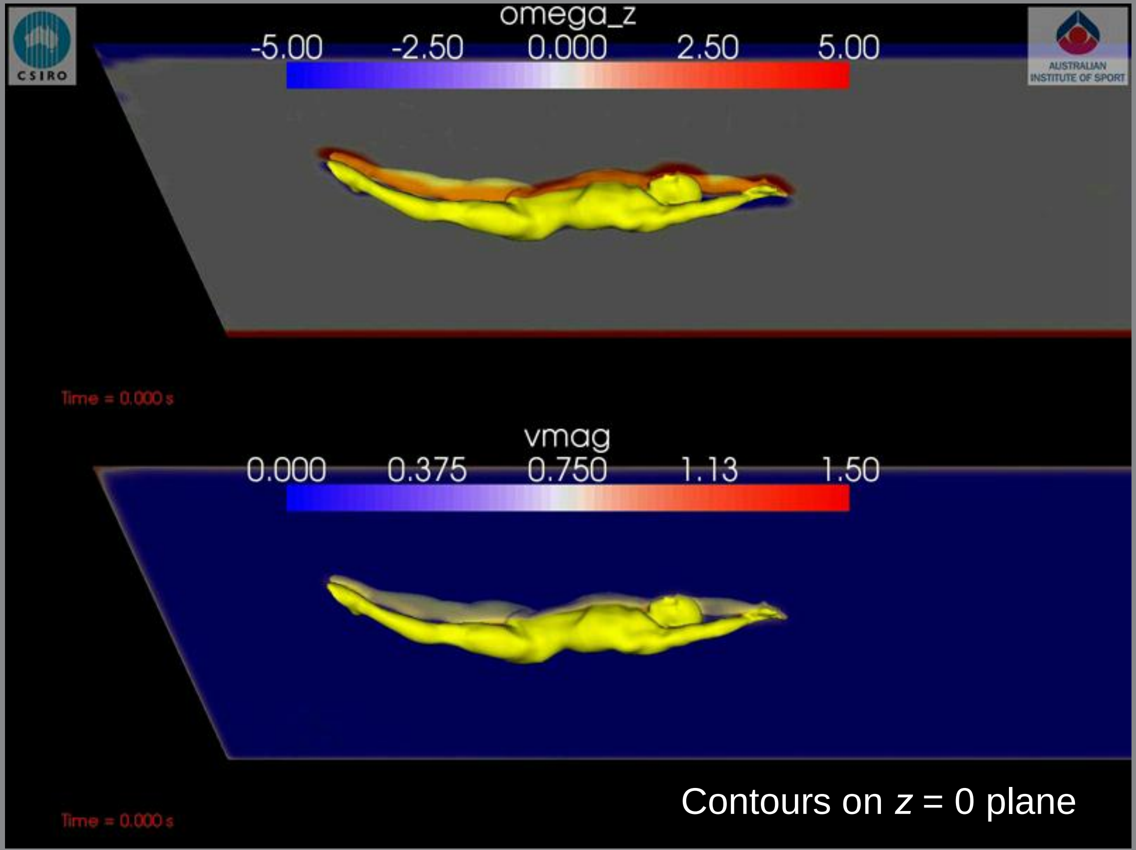
Spanwise vorticity

Velocity magnitude



- High speed / momentum fluid is generated - strongest from extension kick
- Alternately signed vortical structures evident
- Forced vortex shedding interacts with natural shedding

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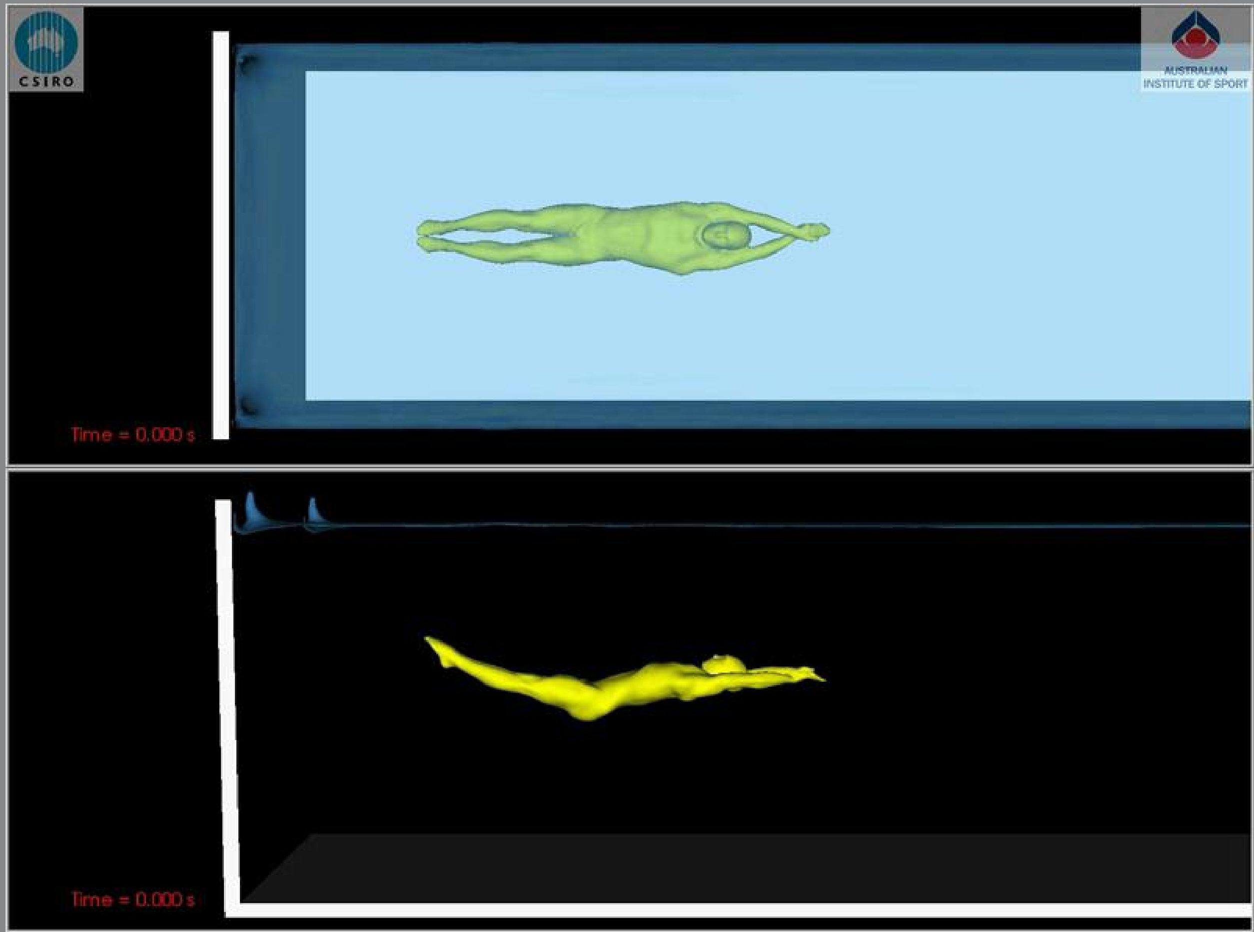
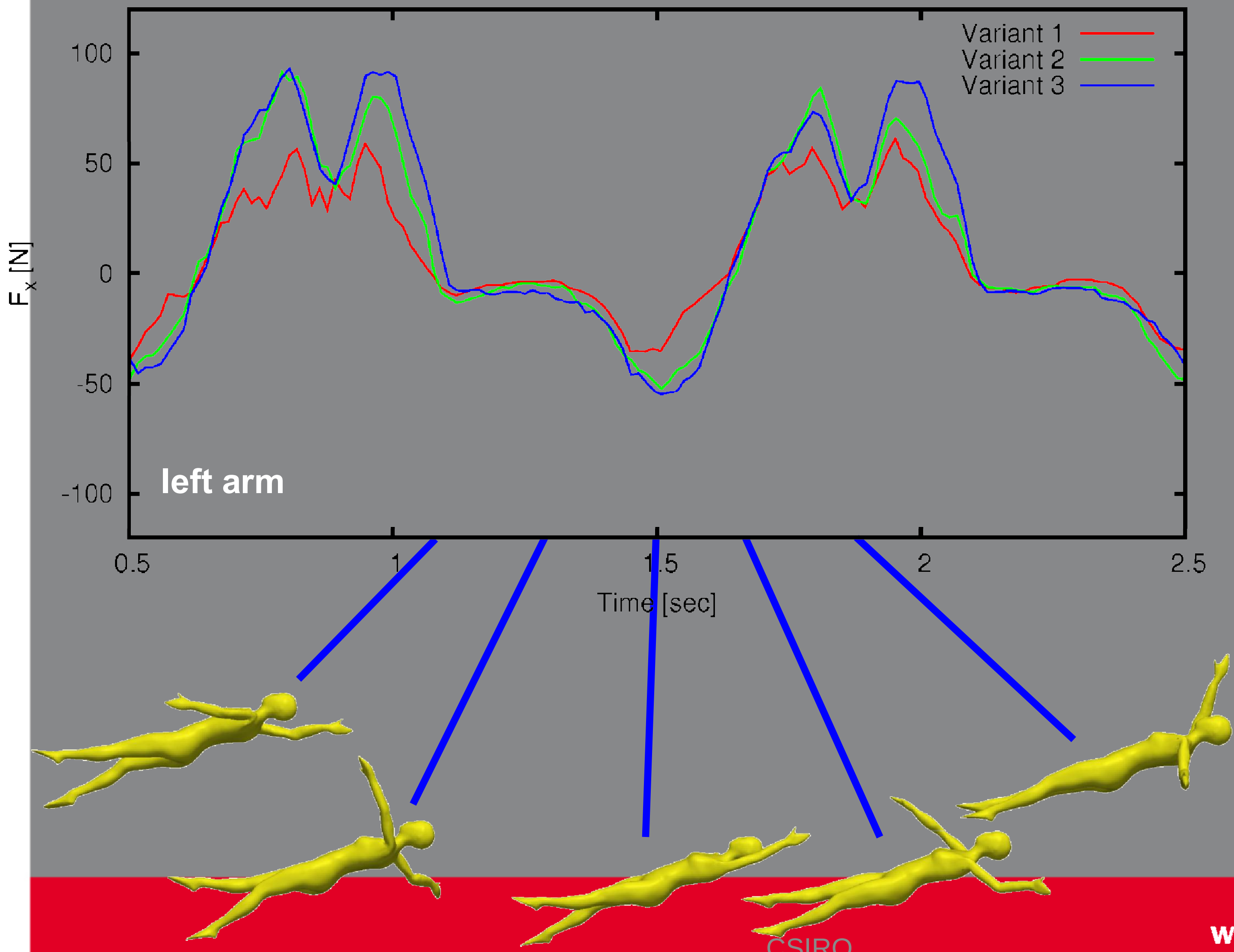
Submerged dolphin kick



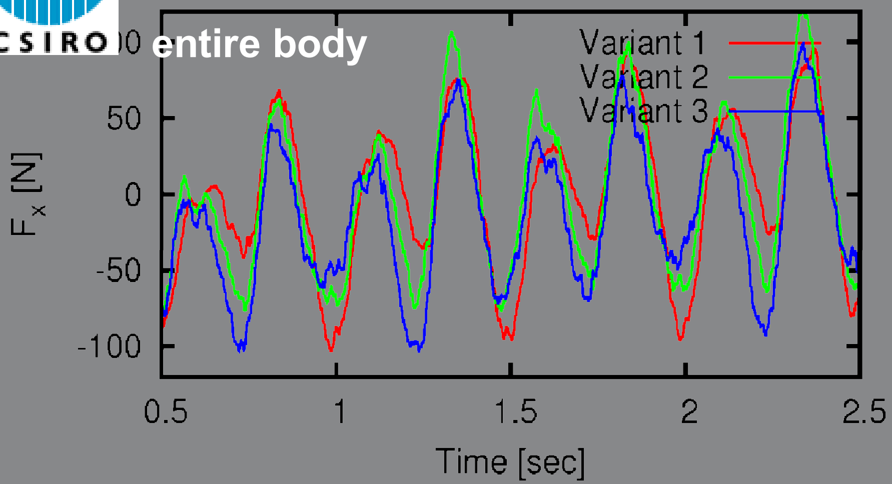
Å ñExtension kickò generates vortex rings associated with major thrust generation

Backstroke u_{∞}=1.5 m/s (specified), f_{stroke}=1 Hz
Forces time history: Left arm

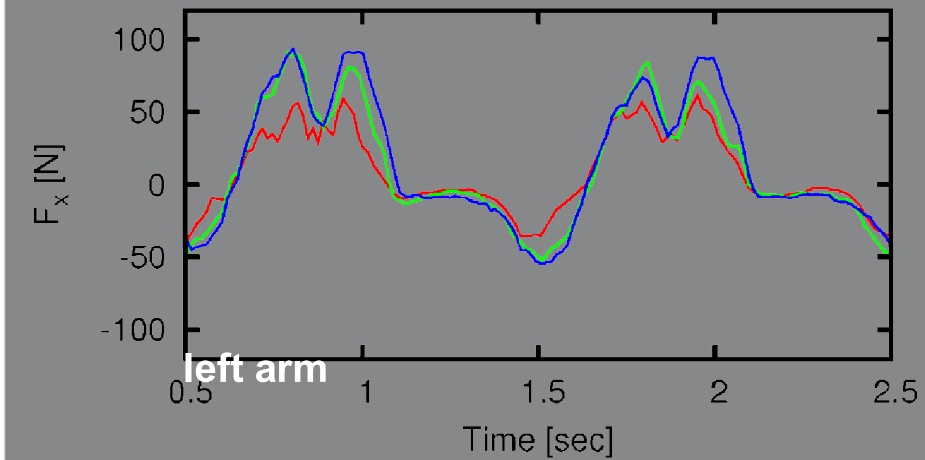


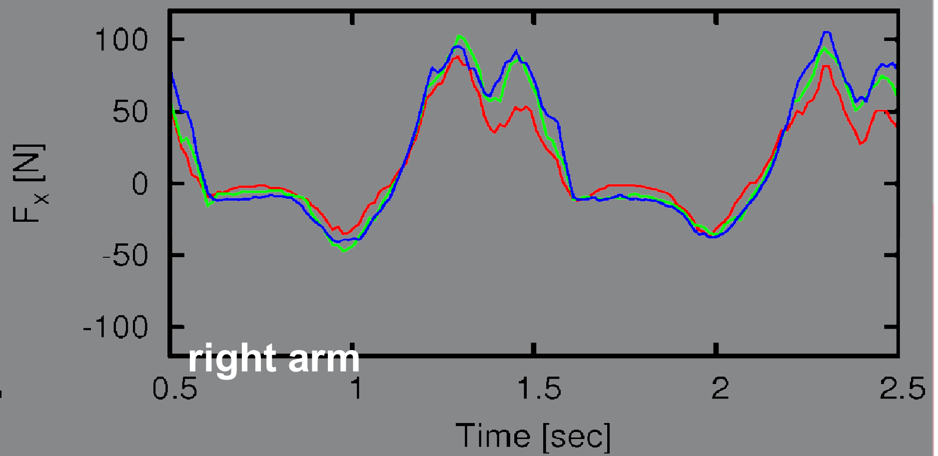
- Negligible force during arm recovery
- Small drag force upon arm entry
- Large positive thrust during propulsive part of stroke

Backstroke u_∞=1.5 m/s (specified), f_{stroke}=1 Hz
Forces time history



- Variants – increasing pitch angle
- 2 major and 2 minor peaks in thrust throughout the stroke period
  - A combined effect of the thrust/recovery/re-entry timings of opposite arms
- How should these be timed to improve the stroke...?





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CFD in Start Analysis 1

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CFD in Start Analysis 2

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CFD in Turn Analysis 1

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Thank you

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