National Aeronautics and Space Administration

Metabolic Expenditures During Extravehicular Activity: Spaceflight *Versus* Ground-based Simulation

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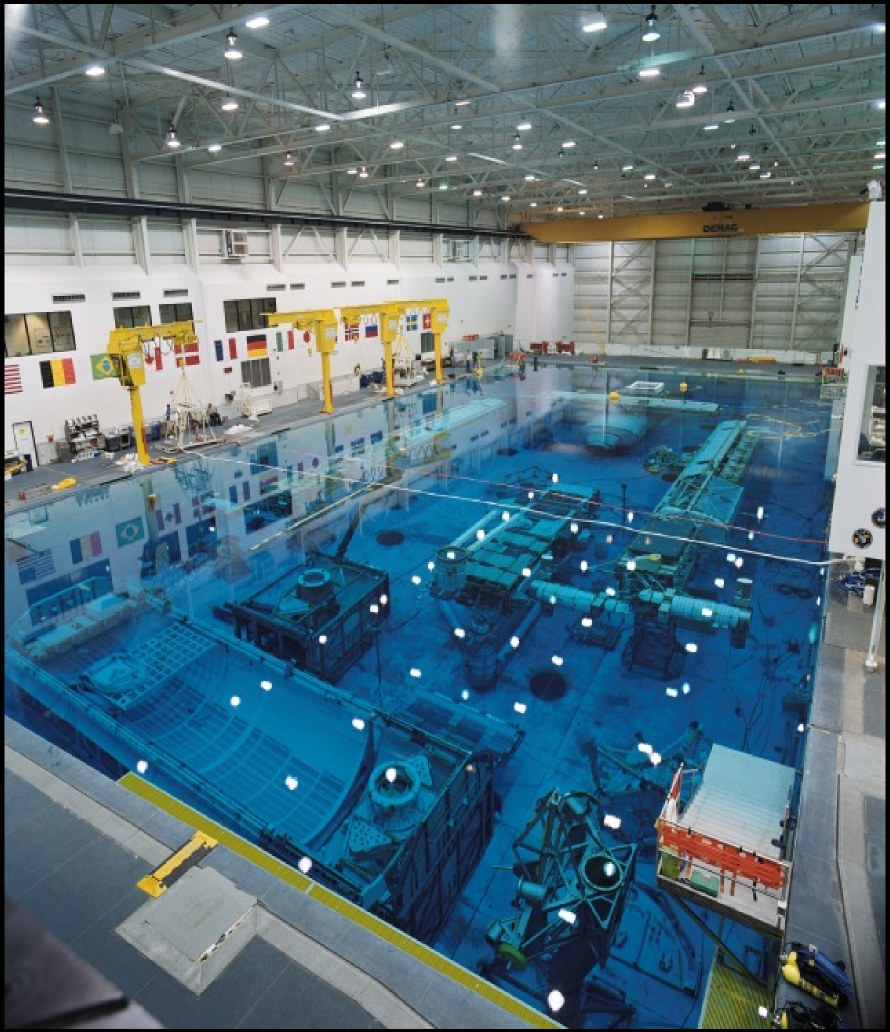
Metabolic Data

- Collected at the Sonny Carter Training Facilities Neutral Buoyancy Lab (NBL)
- To establish a baseline
  - For each crewmember
  - For each Extravehicular Activity (EVA)
    - EVA Acceptance Test (EVAAT) or Final



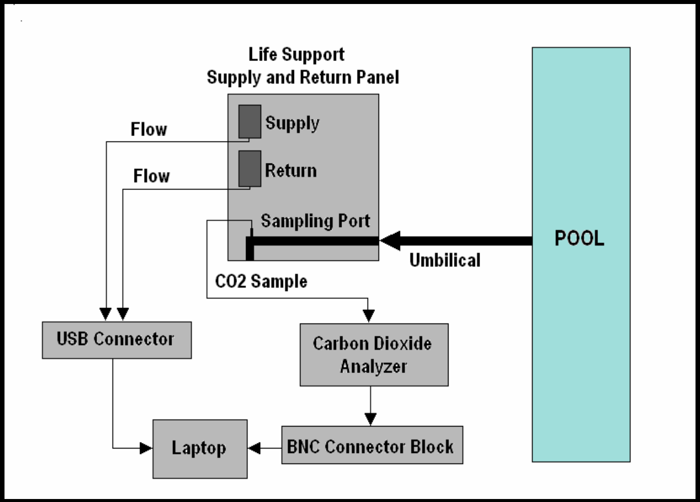
Ground-based Data

Flight Data

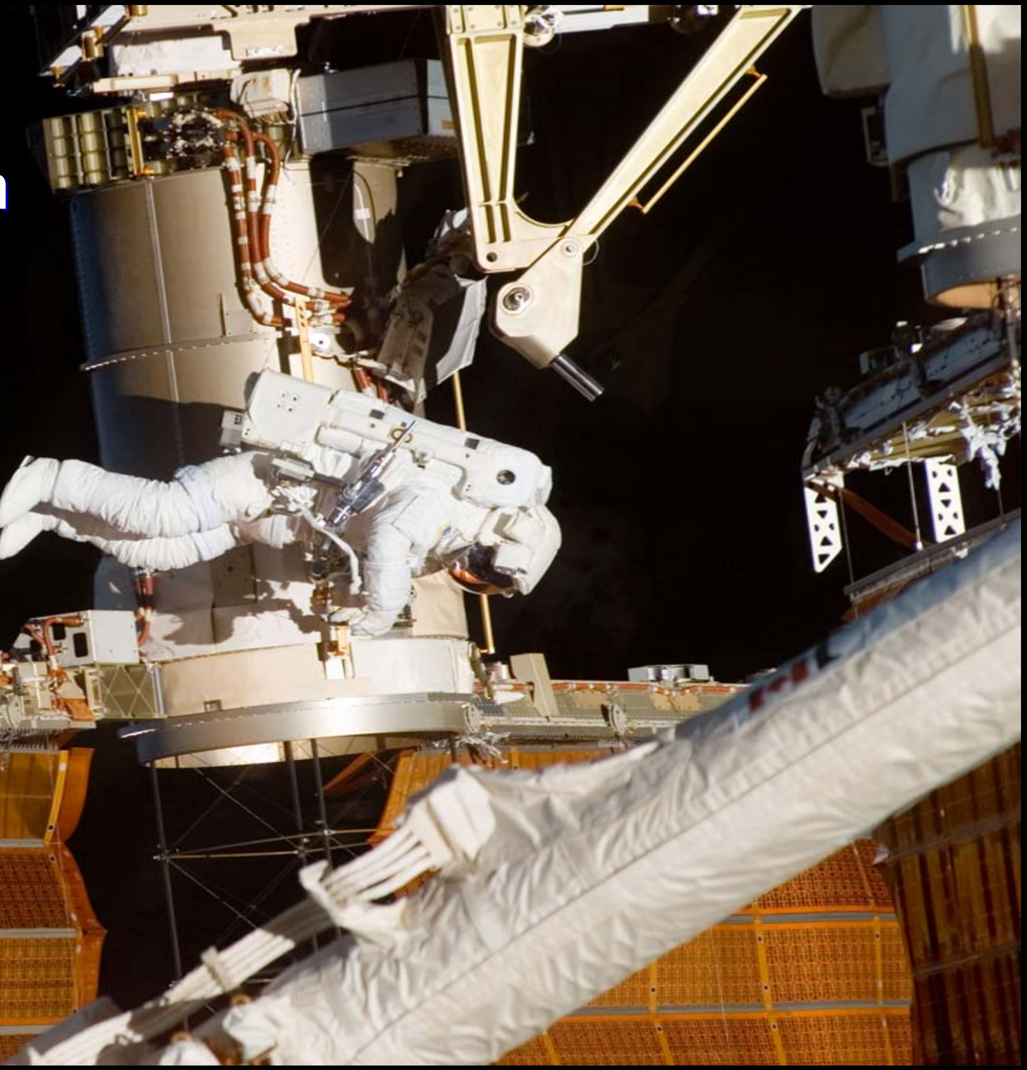
- Monitored during flight
- Processed postflight
- Met rates compared to NBL baseline data

Collection Methods – NBL

- Carbon Dioxide (CO_2)
  - Sampled from return umbilical before venting out
  - Concentration measured using a CO_2 analyzer
- Gas Flow
  - Digital outputs from panel flow meters
  - Both supply and return flow rates measured

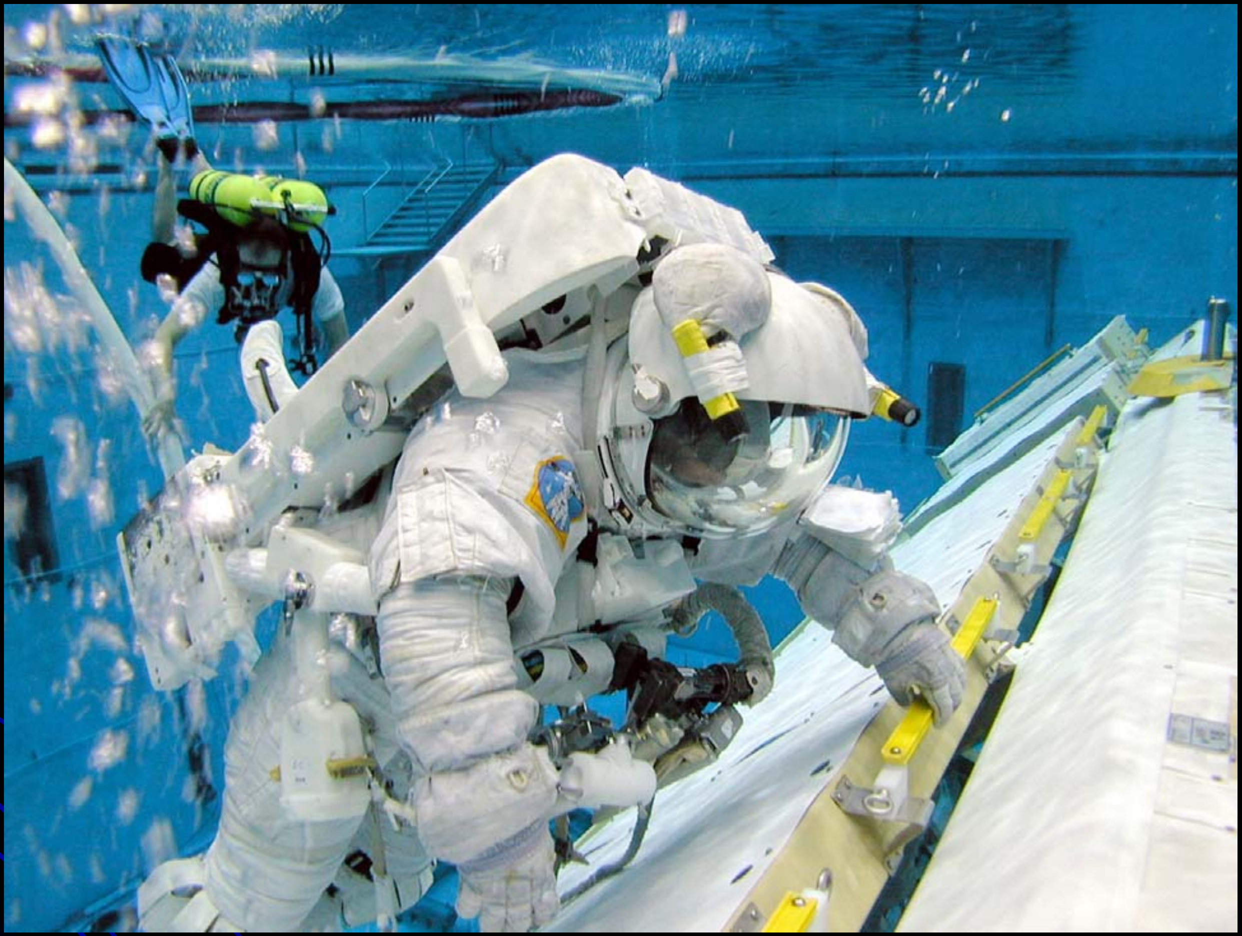


- Oxygen (O_2) Depletion Rate
  - Gauge readings downlinked at 2-minute intervals



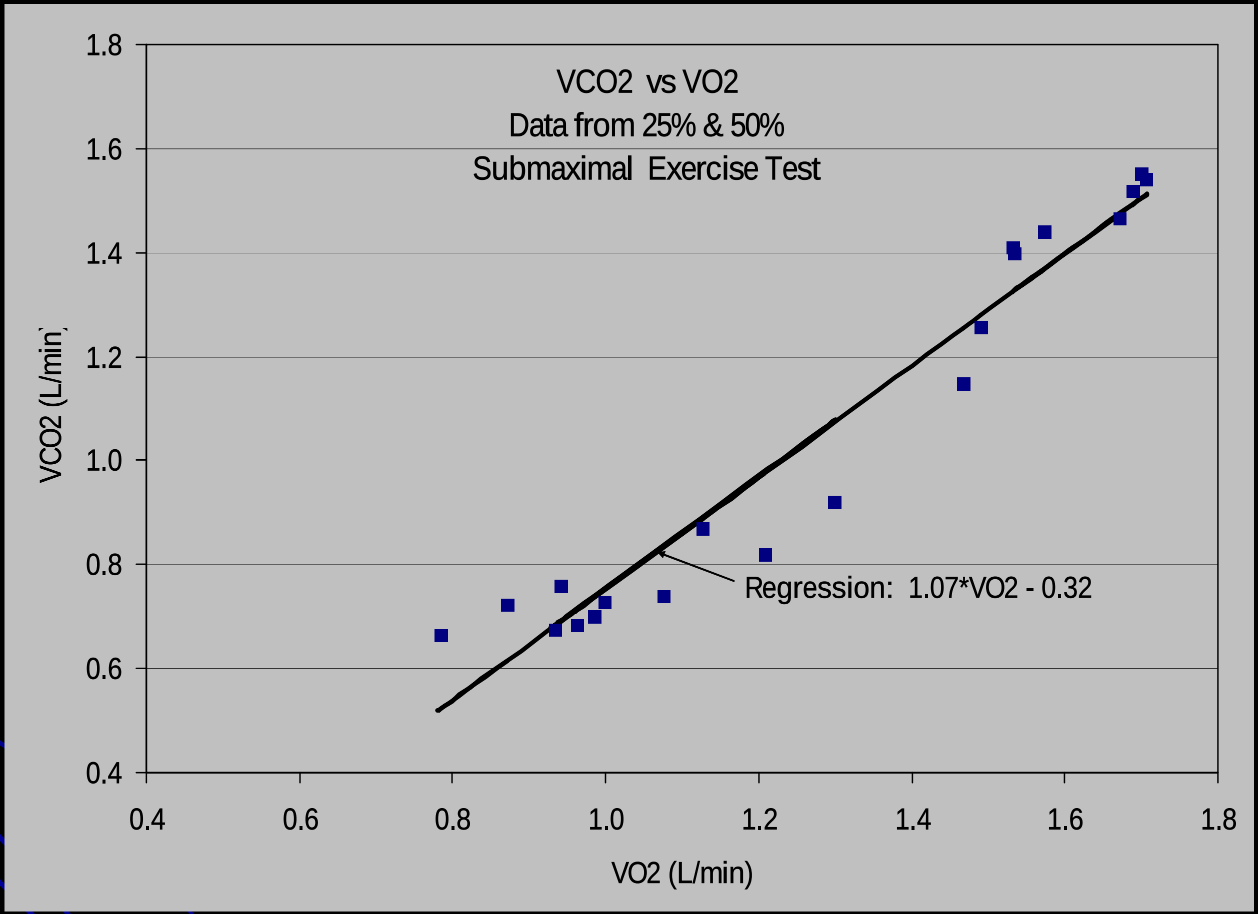
Collection Methods - Flight

VCO_2 = (Flow Rate) x (CO_2 Concentration)



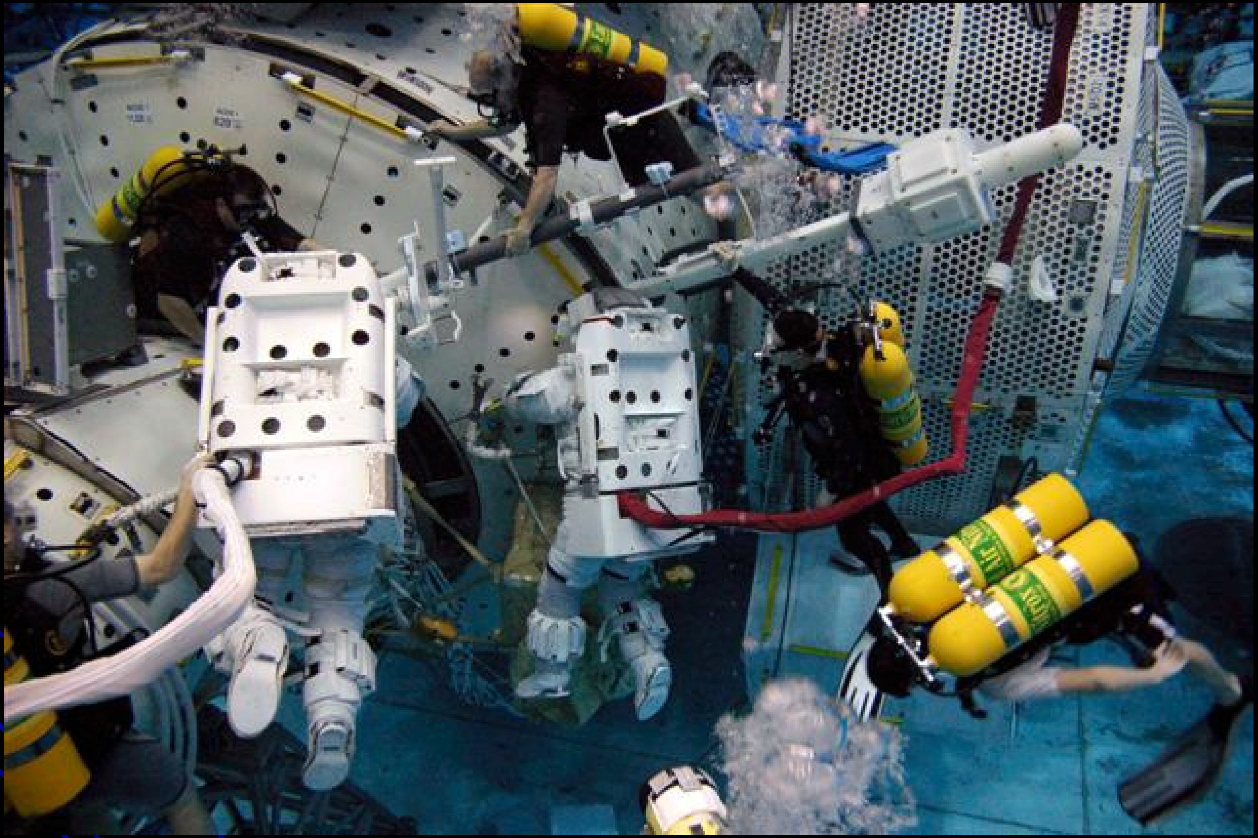
Calculations

$VCO_2 = m \times (VO_2) + b$



Regression

$$\text{Met Rate (kcal/hr)} = 236.5 \times VO_2\ (\text{L/min}) + 66.6 \times VCO_2\ (\text{L/min})$$



Weir Equation

O_2 Depletion Rate (psi /min) = 2.13 x VO_2 (L/min)

O_2 Usage

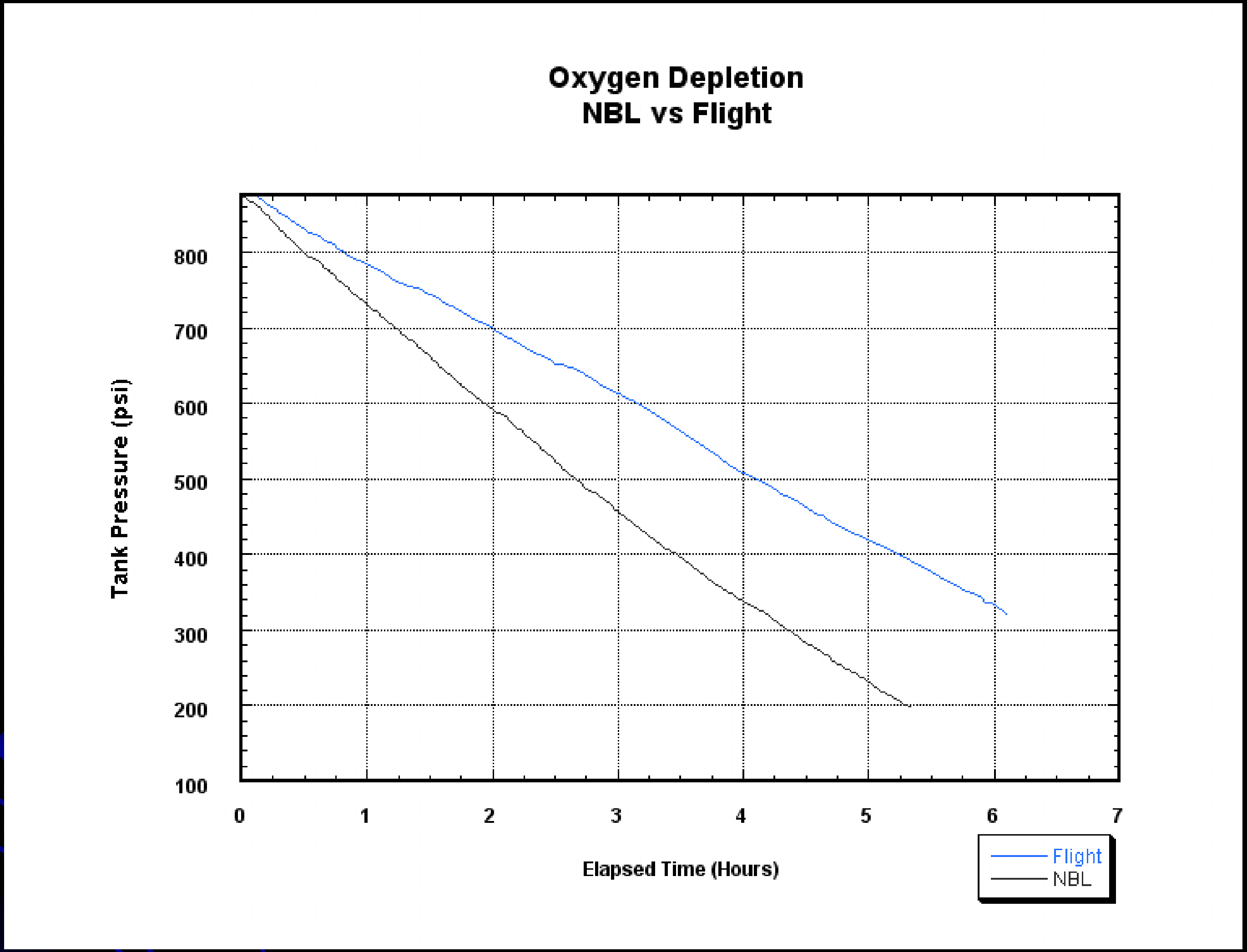
Metabolic Rate - Task Analysis

STS-118 EVA 1
Subject ID Number: 2741

Activity	Time (h:mm)	Met Rate (Kcal/hr)	Met Rate (BTU/hr)	ΔTank Pr. (psi)	Tank Pr. (psi)
Post Depress/Egress/Setup	0:00			0	850
Min		143.18	568.14		
Max		564.39	2239.50		
Average		383.93	1523.42		
O2 depletion				69.81	
S5 to S4 Launch Locks	0:25				780.19
Min		212.97	845.06		
Max		616.03	2444.41		
Average		395.79	1570.48		
O2 depletion				63.32	
S5 Install	0:47				716.87
Min		202.19	802.29		
Max		590.91	2344.73		
Average		404.88	1606.55		
O2 depletion				188.47	
PVRGF Relocate	1:51				528.4
Min		123.03	488.18		
Max		689.56	2736.17		
Average		330.89	1312.99		
O2 depletion				108.2	
S5 to S4 Umbilicals	2:36				420.2
Min		246.91	979.74		
Max		571.11	2266.16		
Average		410.11	1627.31		
O2 depletion				122.3	
S5 Cleanup	3:17				297.9
Min		132.27	524.85		
Max		647.32	2568.57		
Average		387.83	1538.92		
O2 depletion				110	
PVR Retract and Cinch	3:56				187.9
Min		183.75	729.12		
Max		522.24	2072.25		
Average		328.09	1301.87		
O2 depletion				71.59	
Cleanup/Ingress/Prerepress	4:26				116.31
Min		154.78	614.17		
Max		565.53	2244.02		
Average		327.55	1299.71		
O2 depletion				47.62	
	4:46				68.69
Average Met Rate:		375.63	1490.49		
Peak Met Rate:		689.56	2736.17		
Total O2 depletion:				781.31	
Total Met energy expenditure:		1790.49 Kcal	7104.66 BTU		

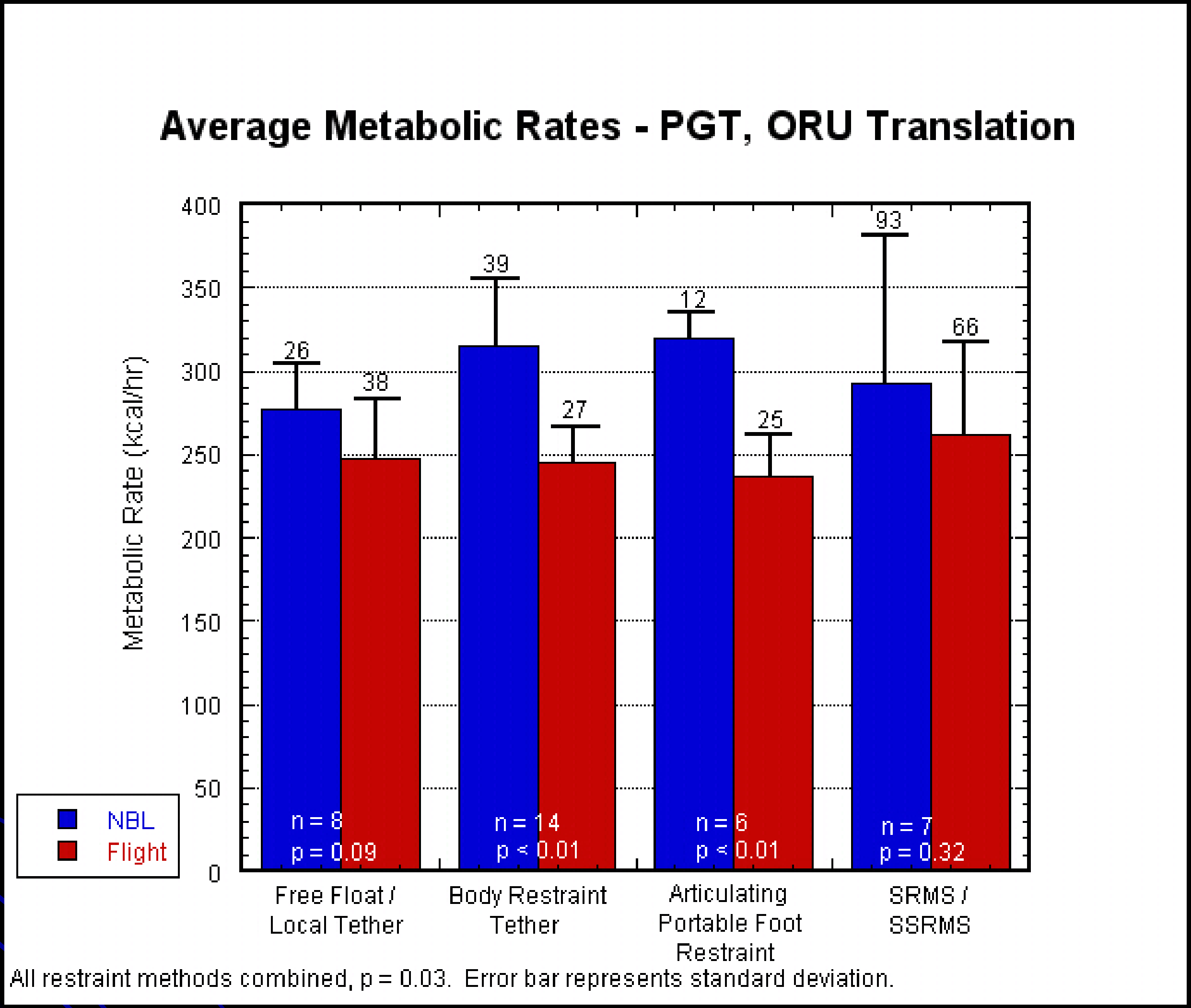
Task Analysis

O_2 Depletion



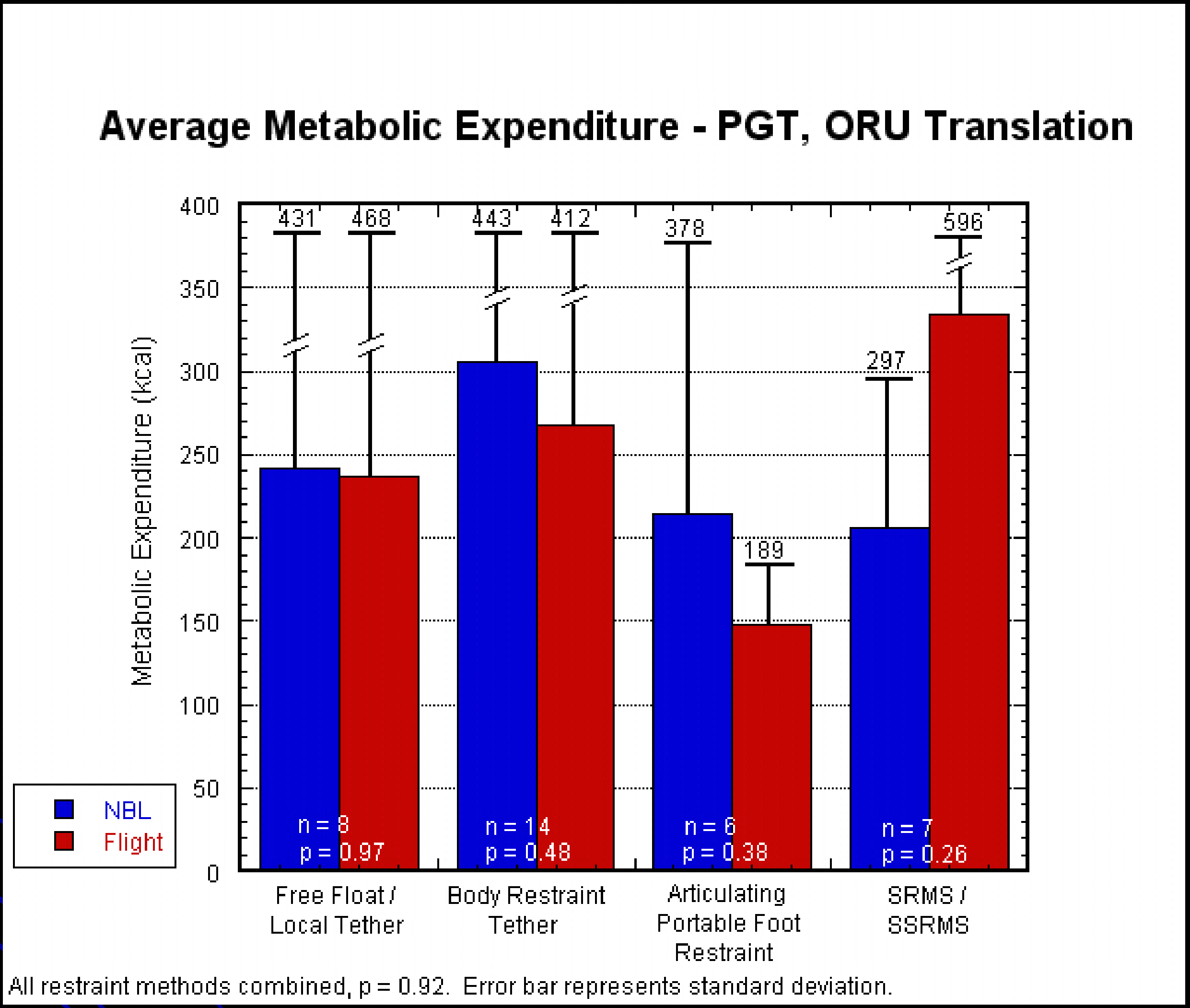
Activity	Met Rate (kcal/hr)
Resting	77
Walking	140
Swimming	500
Tennis	500
Jogging	800
Walking up stairs	1100

Representative Met Rates



Average Metabolic Rates - PGT, ORU Translation
Metabolic Rate (kcal/hr)
400
350
300
250
200
150
100
50
0
26
38
39
27
12
25
93
66
n = 8
p = 0.09
n = 14
p < 0.01
n = 6
p < 0.01
n = 7
p = 0.32
NBL
Flight
Free Float / Local Tether
Body Restraint Tether
Articulating Portable Foot Restraint
SRMS / SSRMS
All restraint methods combined, p = 0.03. Error bar represents standard deviation.

Results



Average Metabolic Expenditure - PGT, ORU Translation
Metabolic Expenditure (kcal)
400
350
300
250
200
150
100
50
0
431
468
443
412
378
596
297
189
n = 8
p = 0.97
n = 14
p = 0.48
n = 6
p = 0.38
n = 7
p = 0.26
NBL
Flight
Free Float / Local Tether
Body Restraint Tether
Articulating Portable Foot Restraint
SRMS / SSRMS
All restraint methods combined, p = 0.92. Error bar represents standard deviation.

Results

- In general metabolic rates tend to be higher in NBL than in flight
  - Restraint method dependant
  - Significant differences between the NBL and flight for BRT and APFR (buoyancy effects)
  - No significant difference between NBL and flight for free float and SRMS/SSRMS operations

- The total metabolic energy expenditure for a given task and for the EVA as a whole are similar between NBL and flight
  - NBL metabolic rates are higher, but training EVAs are constrained to 5 ½ hours
  - Flight metabolic rates are lower, but the EVAs are typically an hour or more longer in duration

- NBL metabolic rates provide a useful operational tool for flight planning

- Quantifying differences and similarities between training and flight improves knowledge for preparation of safe and efficient EVAs

Conclusions