Monitoring the "*Human Machine*"

PHM for Human Assets

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Mark M. Derriso, Ph.D.
Technical Advisor
Airman Systems Directorate
711th Human Performance Wing
Air Force Research Laboratory

AFRL HERITAGE | 1917–2017

100 YEARS OF U.S. AIR FORCE SCIENCE & TECHNOLOGY

Integrity ★ Service ★ Excellence

711th Human Performance Wing

**Advance Human Performance
in Air, Space, and Cyberspace through
Research, Education, and Consultation**

...TO HELP AIRMEN FLY, FIGHT, AND WIN!

Maximize Airman Availability   **Enhance Airman Performance**   **Optimize Resource Efficiency**
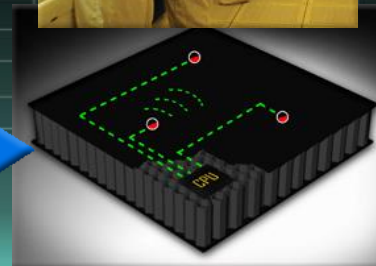
Integrated Systems Health Management

Any system that collects, processes and manages health data to assess the current condition of an aerospace vehicle and determine its ability to perform a given mission.

Determine Ability to Perform Mission

Assess Damage

Detect Damage

Similarities of Human and Machinery Degradation

- **Consider some common vocabulary**

  – Stress, pressure, workload, fatigue, …

- **However, the meaning of the terms is different across fields**

  – Human stress can be mental and/or physical, machinery stress is: (Force/Area)

- **The theme of the common terms is that they indicate factors related to degradation**

Machine versus Human Monitoring: What's the difference?

- **Machine Monitoring**

  - Successful approaches are based on first principles

  - Failure states are mostly known
    - Failure modes and effects analysis (FMEA)

  - Lower unit-to-unit variability

  - No monitoring of cognitive states

- **Human Monitoring**

  - Mental aspects more difficult to map with first principles
    - Emotional and motivational states

  - Failure states could vary from person-to-person

  - Higher unit-to-unit variability

  - Must monitor cognitive states

Performance Myths

- ***Good performance does not guarantee good health***

- ***Good health does not guarantee good performance***

- **Examples**
  - The Bosh Story: Outstanding All-star game with blood clot in lung
  - Michael Jordan: Playing with the Flu
  - Terrell Davis: playing with migraines
  - High wash out rate during Combat Controllers (CCT) and Pararescue (PJ) indoctrination

Operational performance

- ***Operational* Performance:** accomplishing trained activity by using bodily control for enacting tooled capacities, within a environing domain while coordinating with ensembles of others.

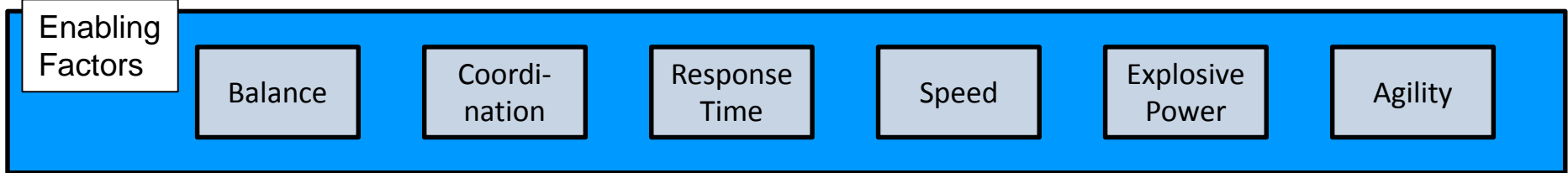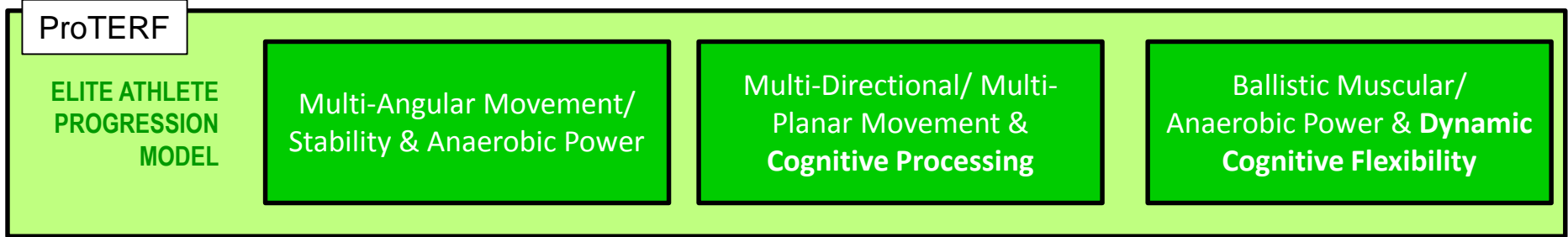# Elite Performance Factors

Professional Athletes

Military/Tactical Athletes

- ✓ Explosive Power
- ✓ Balance
- ✓ Response Time
- ✓ Speed
- ✓ Coordination
- ✓ Agility

Training Models:
ACE to PROTERF Progression

ProTERF

ELITE ATHLETE PROGRESSION MODEL

| Multi-Angular Movement/ Stability & Anaerobic Power | Multi-Directional/ Multi-Planar Movement & **Cognitive Processing** | Ballistic Muscular/ Anaerobic Power & **Dynamic Cognitive Flexibility** |

Enabling Factors

| Balance | Coordi-nation | Response Time | Speed | Explosive Power | Agility |

ACE

FUNCTIONAL MOVEMENT & RESISTANCE TRAINING

| Stability & Mobility | Movement | Load | Performance |

Phase 1 | Phase 2 | Phase 3 | Phase 4

CARDIORESPIRATORY TRAINING

| Aerobic-base | Aerobic-efficiency | Aerobic-endurance | Aerobic-power |

Factors and Assessments

- **Balance, Coordination, Response Time, Speed, Explosive Power, and Agility**
  - Based on extending framework of American Council on Exercise (ACE)

- **In initial study, three drills conducted to test factors**
  - Specifically tests both physical and cognitive elements

- **Assessments quantify outcome and technique**
  - Professional trainer rates each drill
  - Computed assessments from full body wireless motion capture data*

* Xsens MVN Awinda Biomech and MVN Studio Software

Computational Assessments

Algorithms process sensor data to match training specialist

– Algorithms to compute assessments

  • Near term: Degree that fundamental factors were exhibited
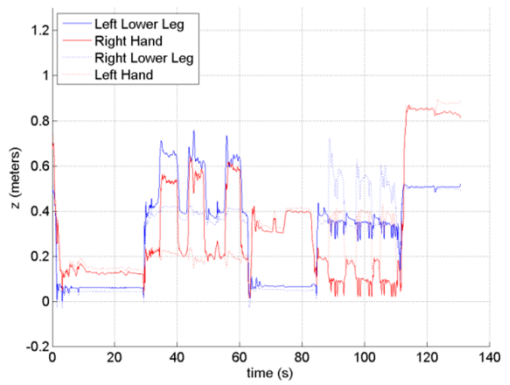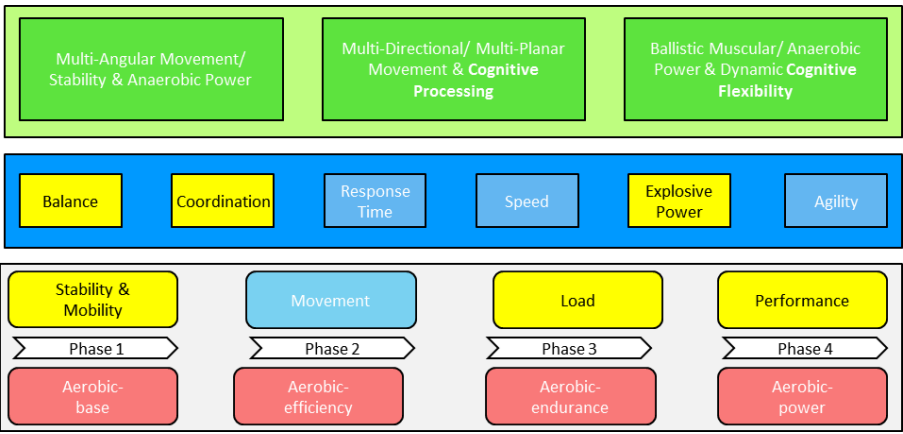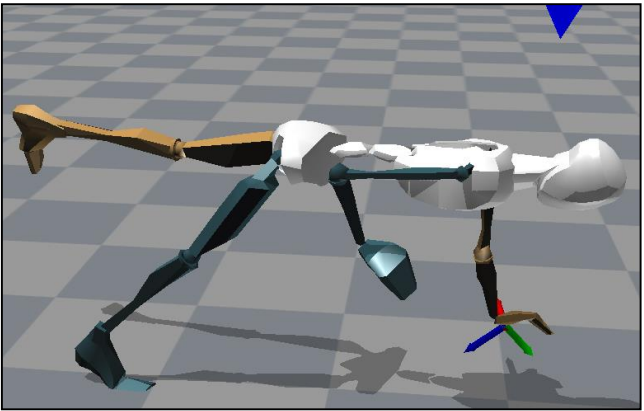
  • Longer term: Overall rating of mission readiness

$$\text{Signal Processing} \rightarrow \text{Computational Assessments} \rightarrow \text{Mission Readiness Rating}$$
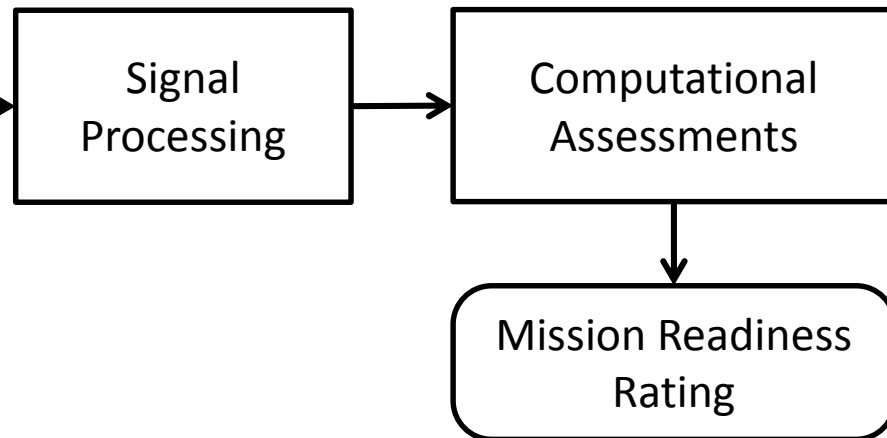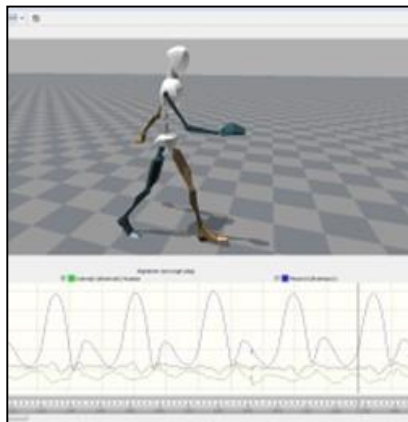
position, velocity, acceleration, orientation, angular velocity and angular acceleration of body segments and joints
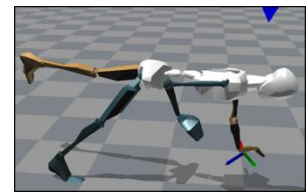
Balance – Lock and Load

+z

Multi-Angular Movement/ Stability & Anaerobic Power	Multi-Directional/ Multi-Planar Movement & **Cognitive Processing**	Ballistic Muscular/ Anaerobic Power & Dynamic **Cognitive Flexibility**

Balance	Coordination	Response Time	Speed	Explosive Power	Agility

Stability & Mobility	Movement	Load	Performance
Phase 1	Phase 2	Phase 3	Phase 4
Aerobic-base	Aerobic-efficiency	Aerobic-endurance	Aerobic-power

Balance – Quantified

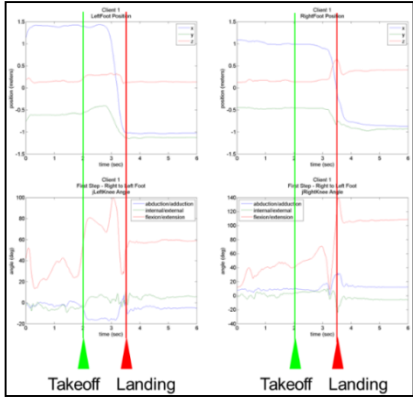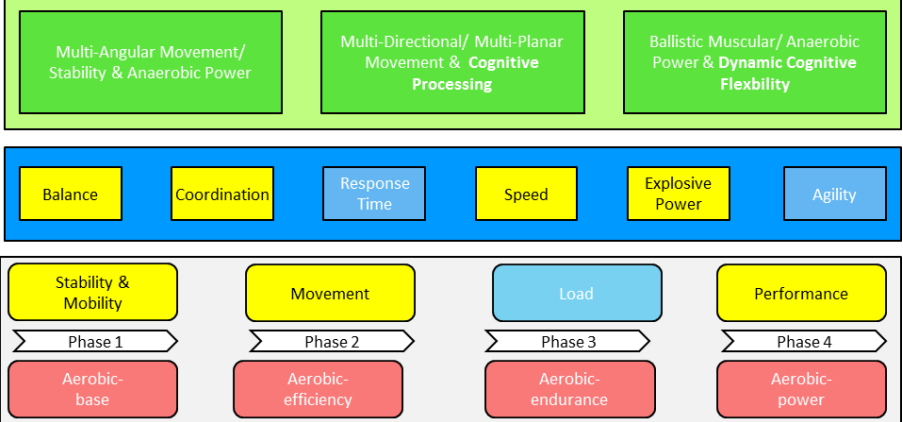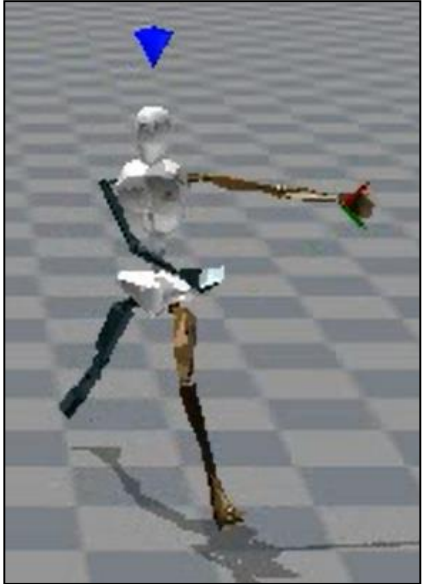| Client	Trial		Standard Deviation of Z-Position (mm)				Normalized Scores		Leg Avg
			Left Hand	Right Hand	Left Lower Leg	Right Lower Leg	Hands	Lower Legs	
1	Lift Right Arm, Left Leg	1	4.9	8.5	28.4	1.3	1.74	21.55	10.7
		2	6.8	7.7	6.8	3.3	1.13	2.06	
		3	7.8	3.3	10.1	1.2	0.43	8.59	
	Lift Left Arm, Right Leg	1	13.6	6.2	4.4	14.3	2.20	3.20	5.5
		2	6.7	2.1	1.8	12.0	3.17	6.70	
		3	9.1	5.3	2.3	24.6	1.74	10.64	
		4	12.1	6.8	9.7	12.5	1.77	1.29	
2	Lift Right Arm, Left Leg	1	4.7	9.5	7.5	1.1	2.03	6.65	5.7
		2	20.3	33.9	41.4	10.6	1.67	3.90	
		3	11.1	11.4	14.9	2.3	1.03	6.47	
	Lift Left Arm, Right Leg	1	27.9	20.9	23.4	49.5	1.34	2.12	1.8
		2	24.4	23.2	22.5	30.9	1.05	1.37	
		3	27.2	22.1	21.2	39.2	1.23	1.85	

Legs
Hands
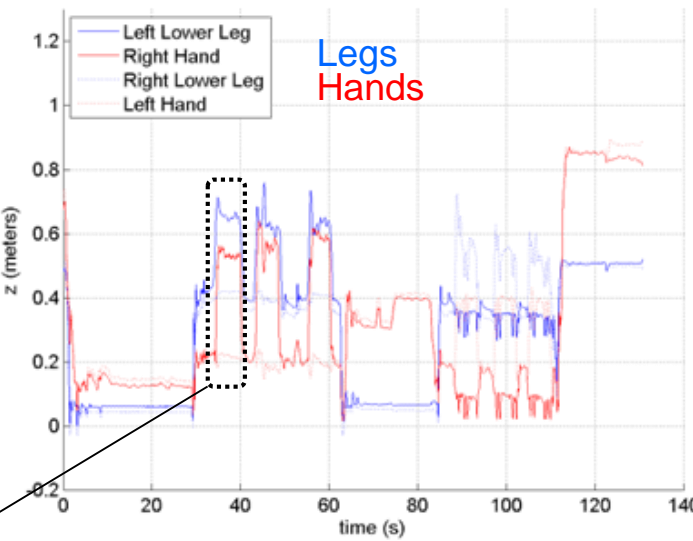
- **Relative stability of raised limb to grounded limb**

- **Consider additional metrics for better assessment of technique**
  - **Joint angle information**
  - **Left / Right Asymmetry**
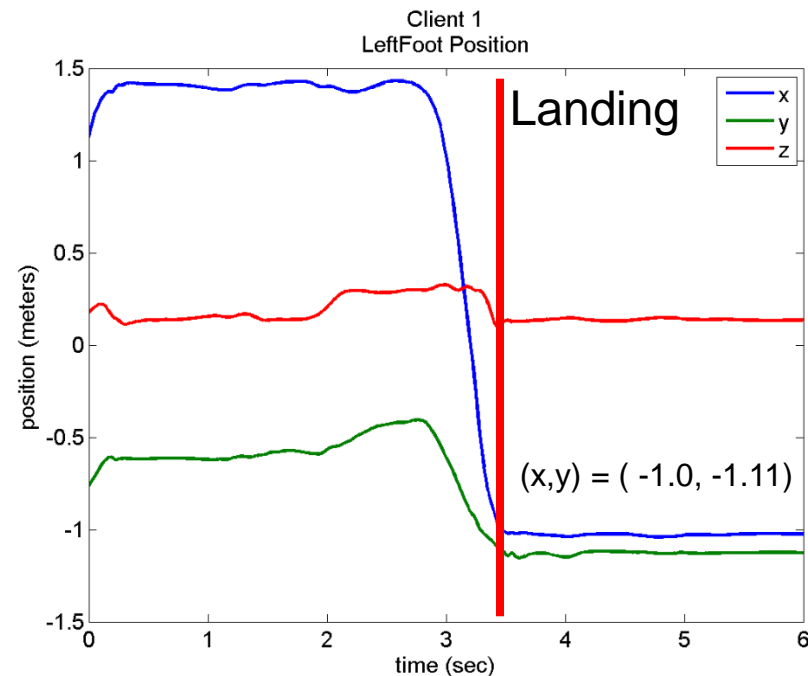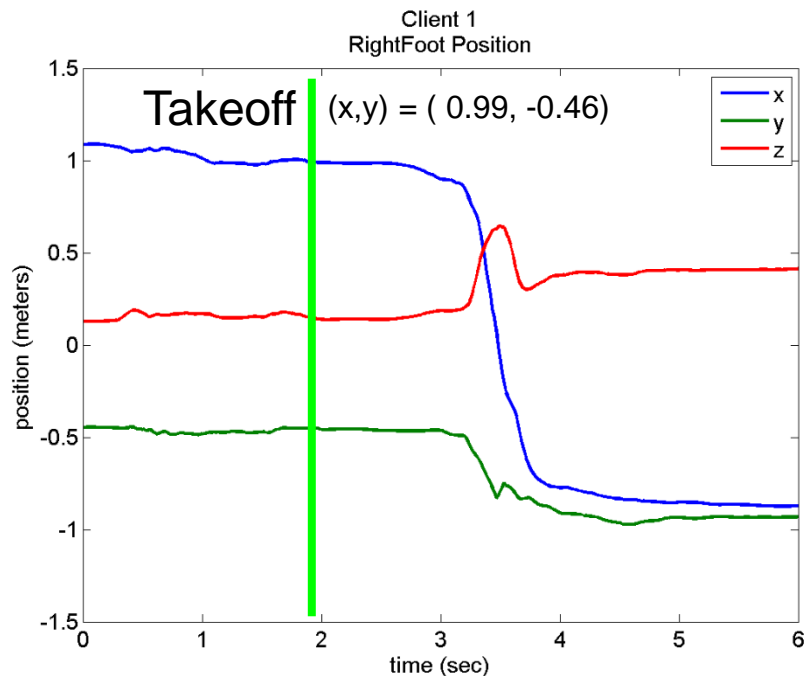
Explosive Power – First Step

Multi-Angular Movement/ Stability & Anaerobic Power	Multi-Directional/ Multi-Planar Movement & **Cognitive Processing**	Ballistic Muscular/ Anaerobic Power & **Dynamic Cognitive Flexbility**

Balance	Coordination	Response Time	Speed	Explosive Power	Agility

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Foot Position

Knee Angle

Takeoff Landing   Takeoff Landing

Explosive Power – Quantified

Client 1
RightFoot Position

Takeoff   (x,y) = (0.99, -0.46)

Client 1
LeftFoot Position

Landing

(x,y) = (-1.0, -1.11)
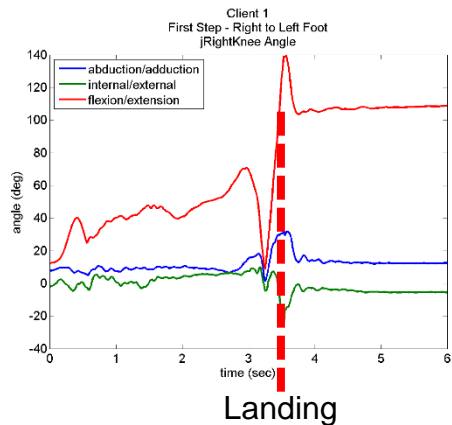
Outcome: Distance of step = 2.08 meters

– **From initial position of right foot to final position of left foot**

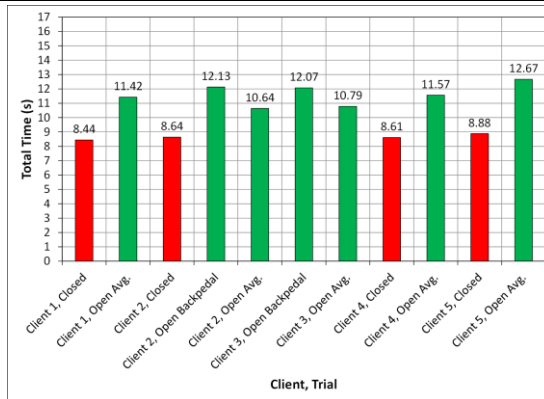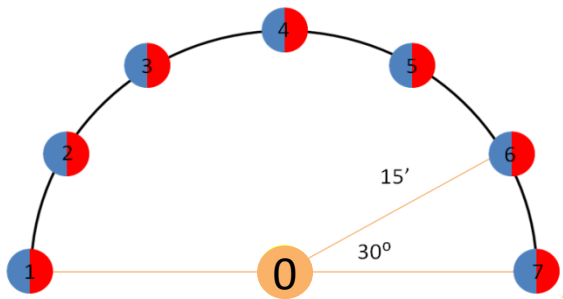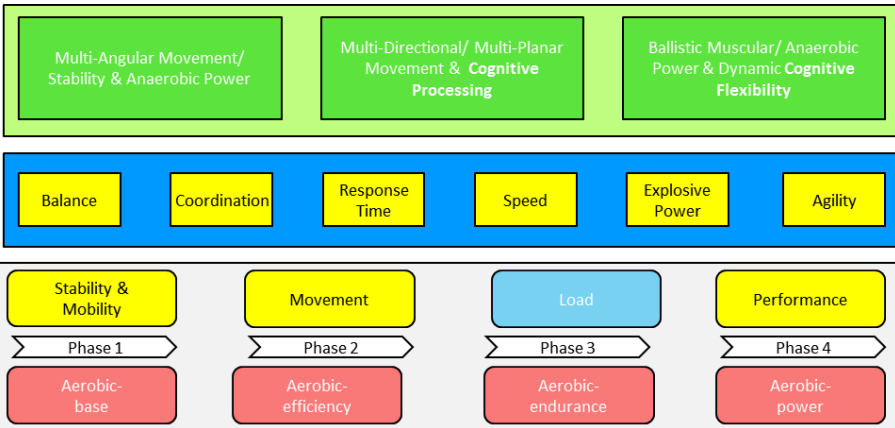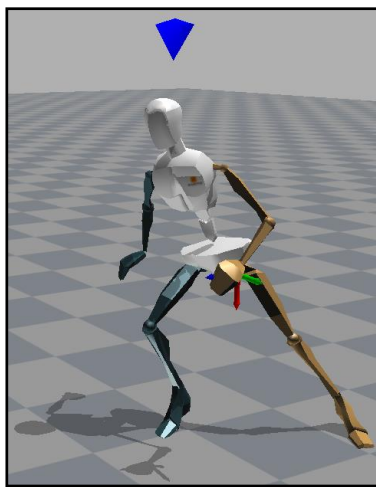# Balance/Coordination – Quantified

Knee Joint Angles
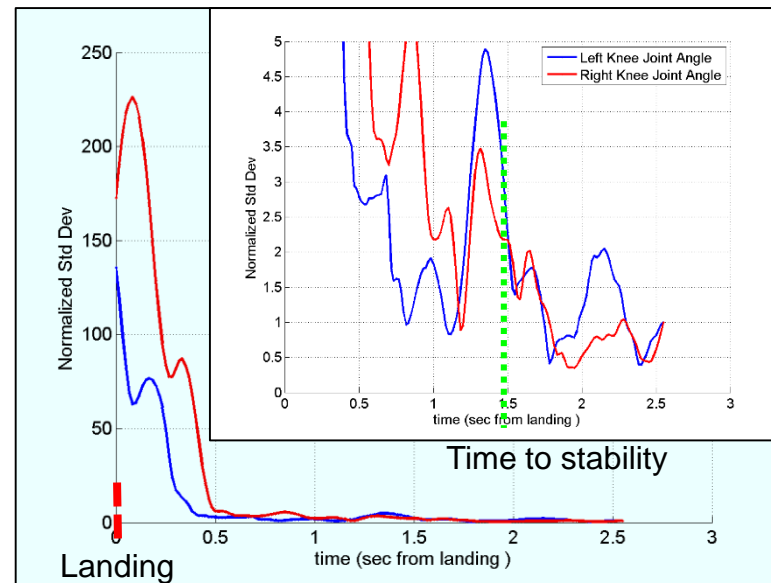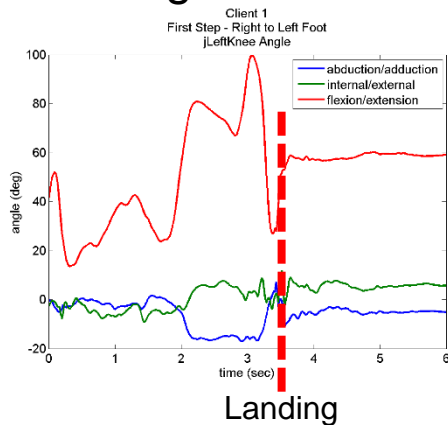
Technique: Time to establish stability = 1.48 seconds

– **Time from landing until normalized standard deviation of knee joint flexion/extension angles remains less than 3**

Agility – D4 Course

Closed vs. Open Skills

Closed Skills: knowing location of next target before action

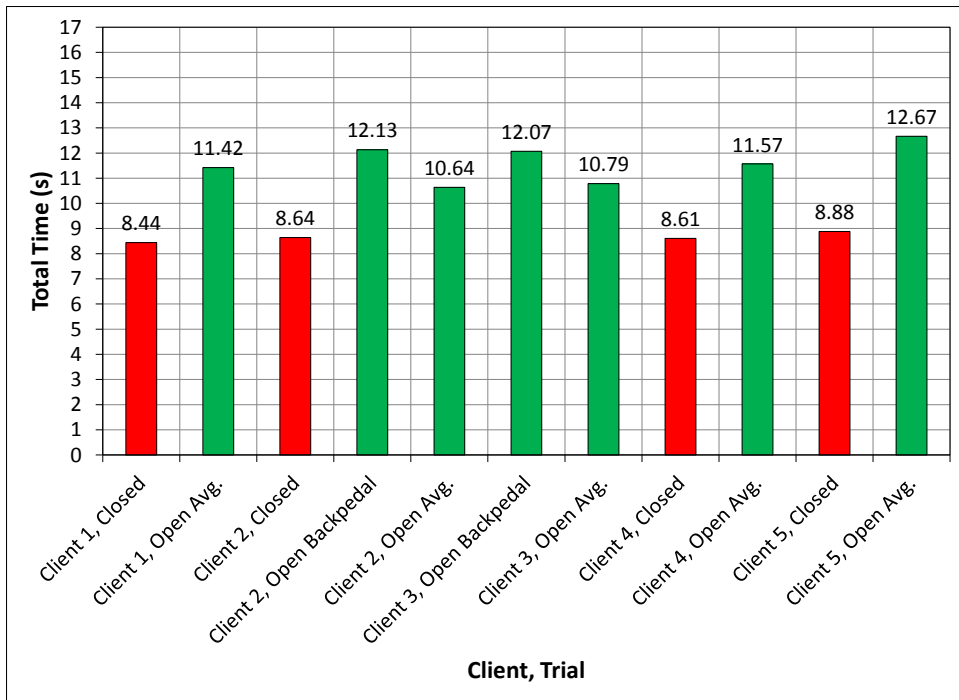**Open Skills: acting, then realizing target is in another direction**

Agility – Quantified

4 Repetitions of D4 course: 1 closed trial, 3 open trials

$$Q = \frac{time_{open}}{time_{closed}}$$

| Client	Time, Closed	Time, Open	Q
1	8.44	11.42	1.35
2	8.64	10.64	1.23
3	NA	10.79	NA
4	8.61	11.57	1.34
5	8.88	12.67	1.43

Summary

- **Elite operational performance requires proper responses to unexpected events or forces**
  - Requires both physical and mental agility
  - Jointly training physical and mental domains improves mission success
  - Current efforts quantify fundamental factors

- **Future Work**
  - Study to quantify improvements in operational performance based on integrated physical and mental training
  - More clients and drills, mapping trainer's assessment of mission readiness to computed assessment of mission readiness
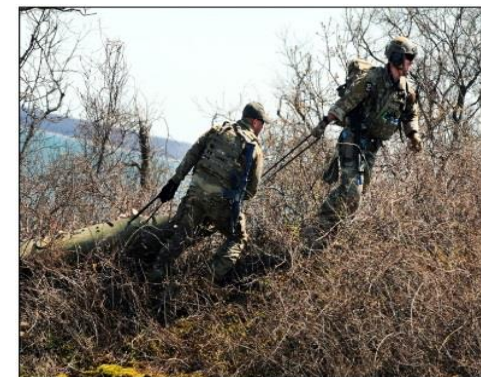
Acknowledgements

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