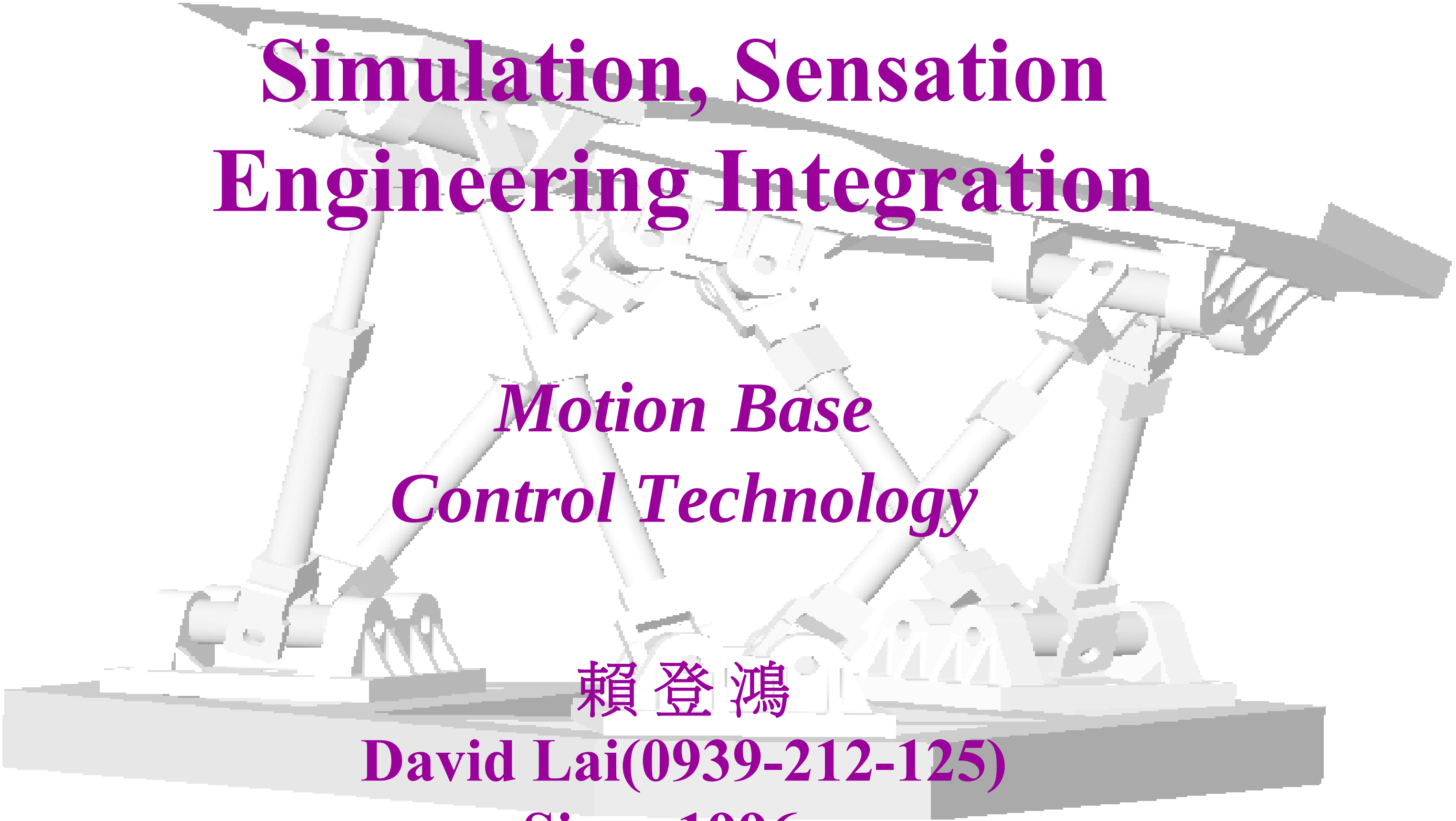


Simulation, Sensation Engineering Integration

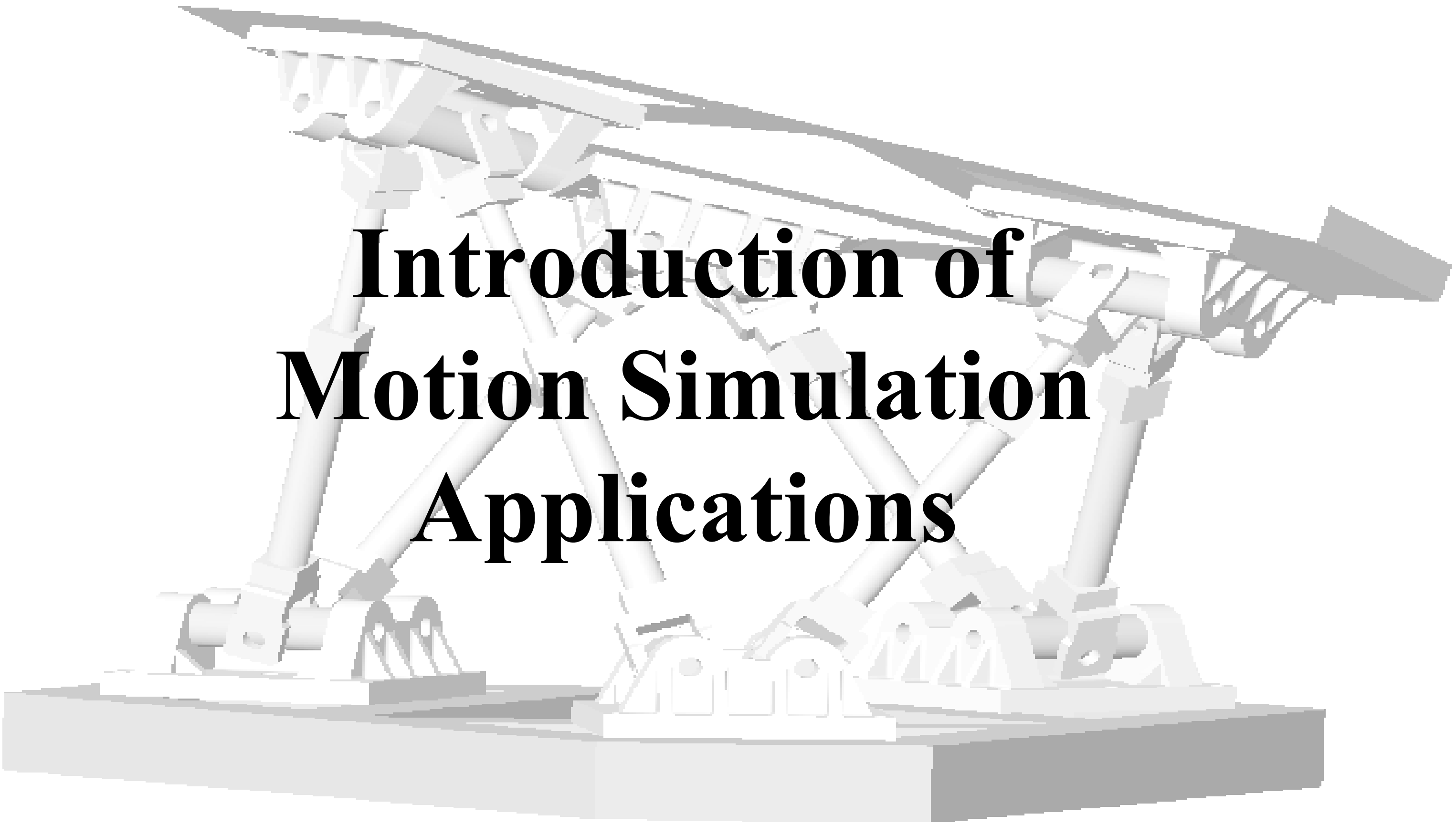
Motion Base Control Technology

賴登鴻

David Lai(0939-212-125)

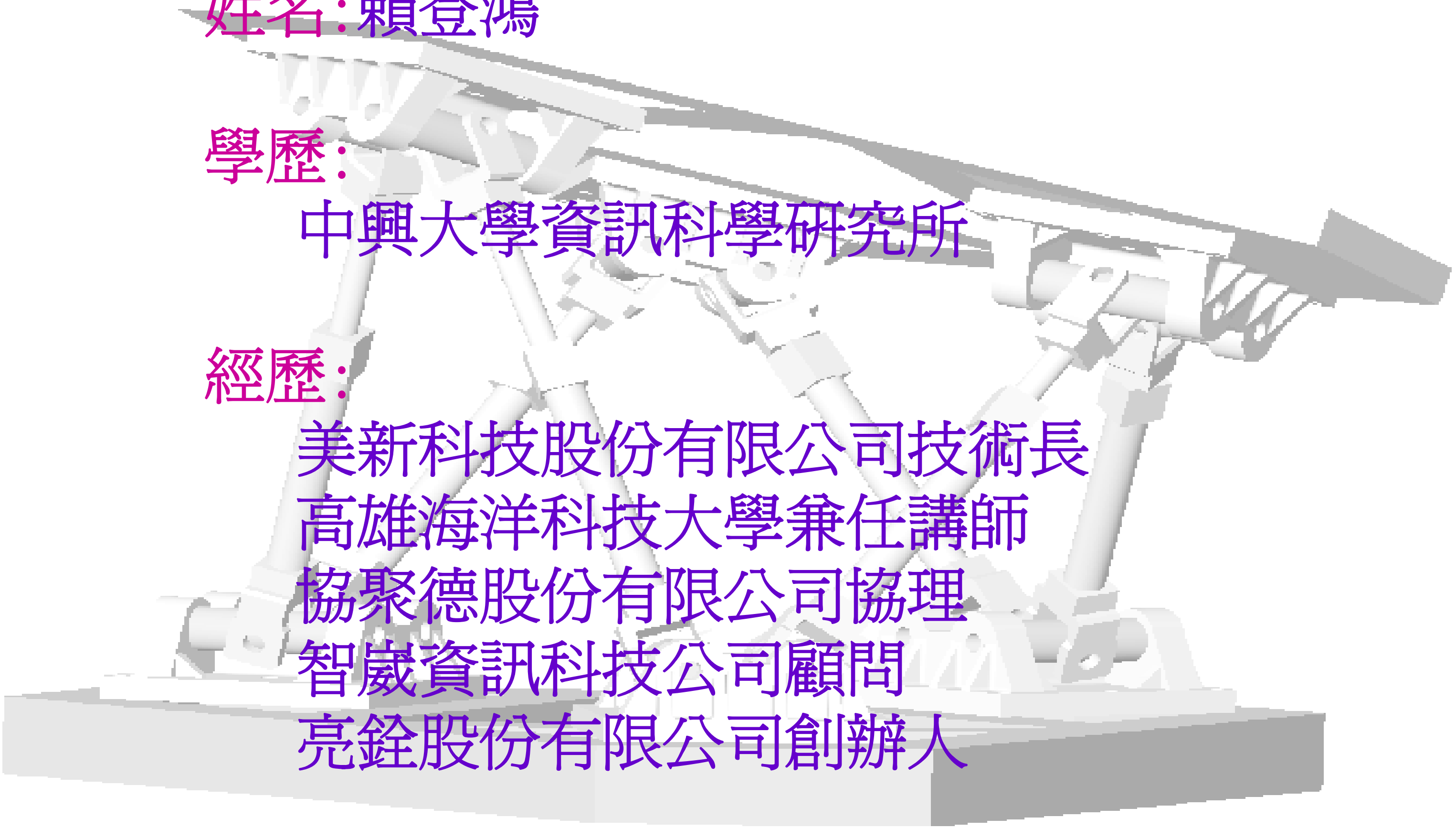
Since 1996 ~

Subject



Introduction of
Motion Simulation
Applications

Resume



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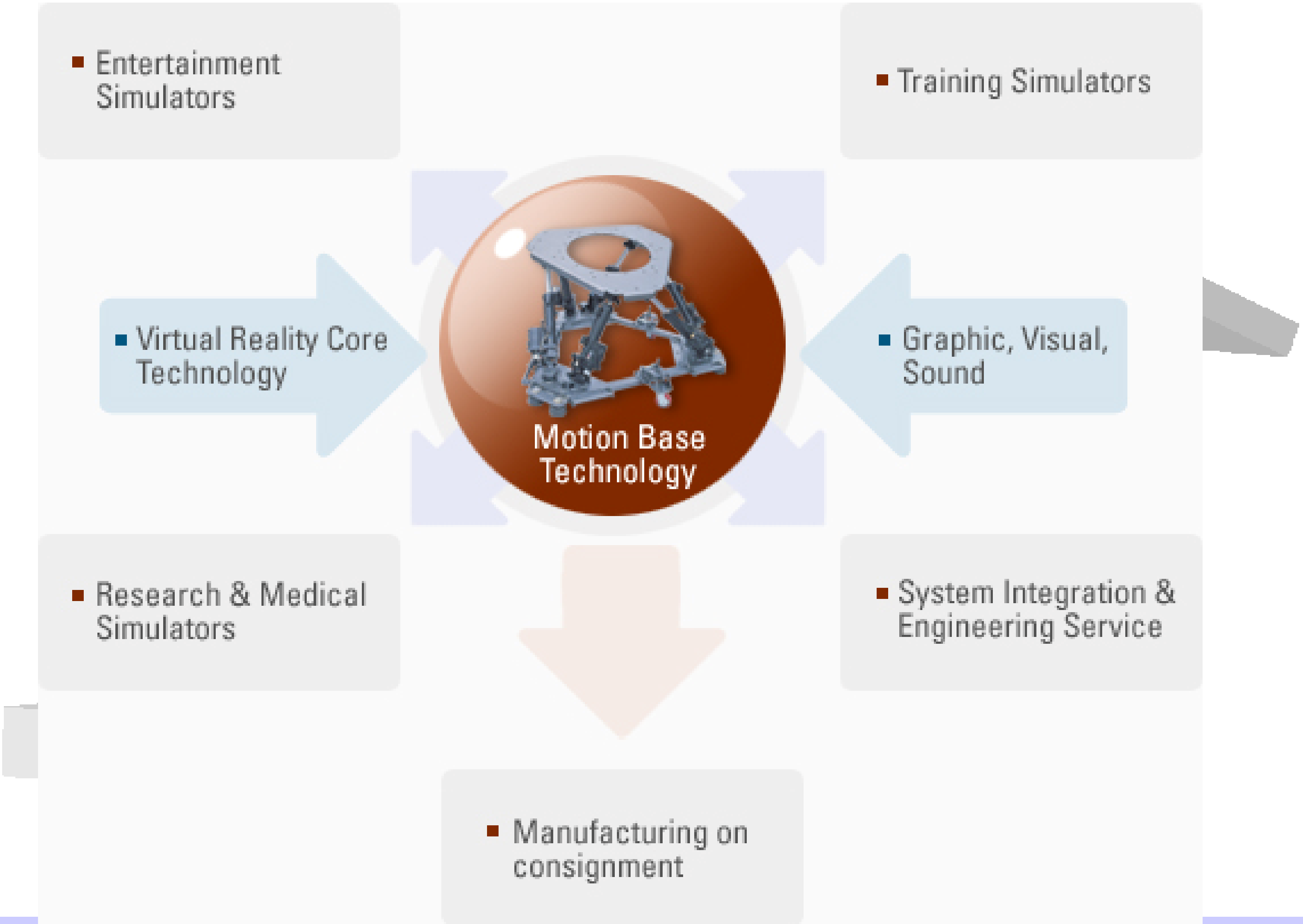
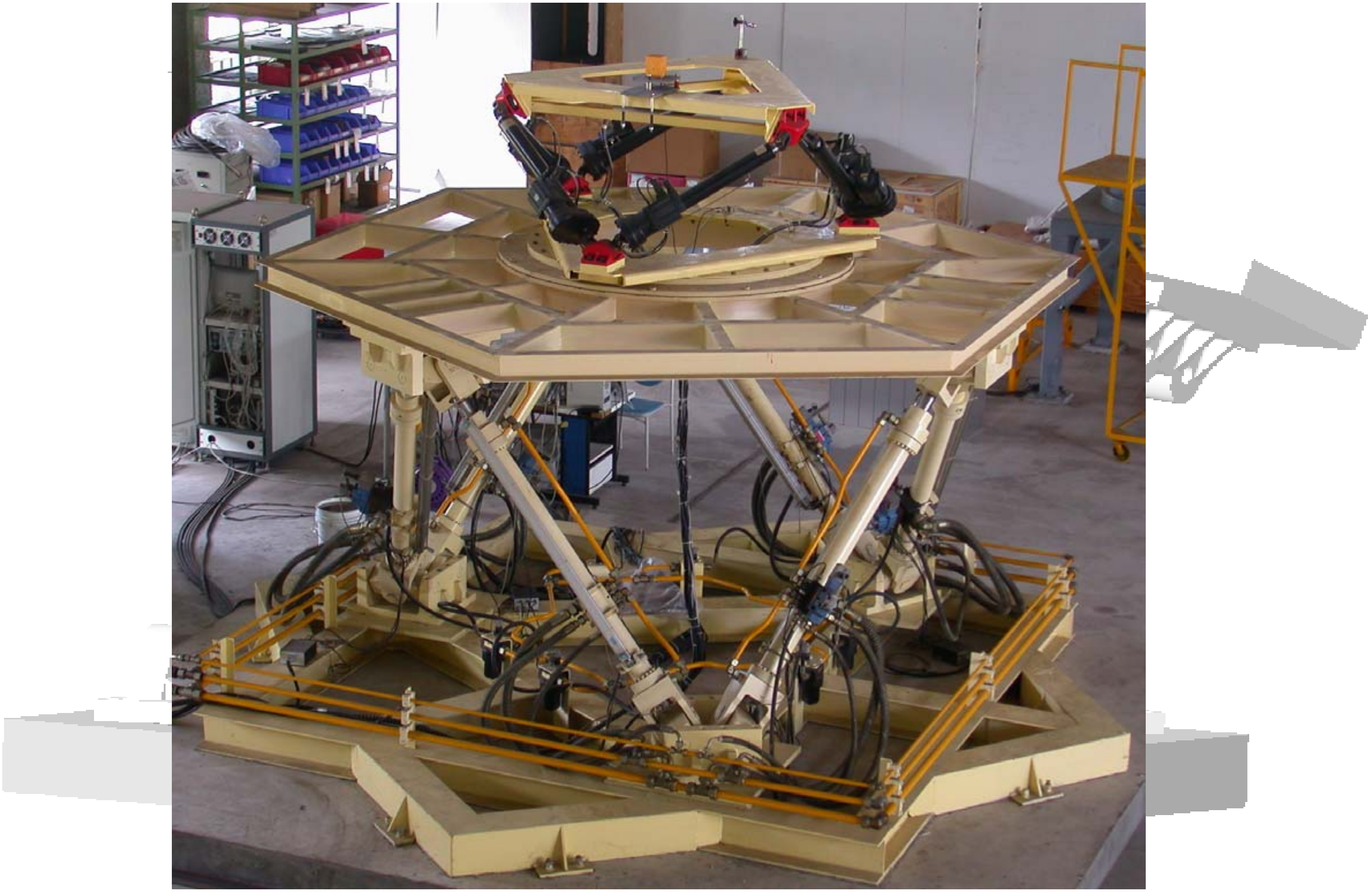
高雄海洋科技大學兼任講師
協聚德股份有限公司協理
智崴資訊科技公司顧問
亮銓股份有限公司創辦人

Business Model



Training



Train

Taiwan Railway EMU 600 Simulator

Boat

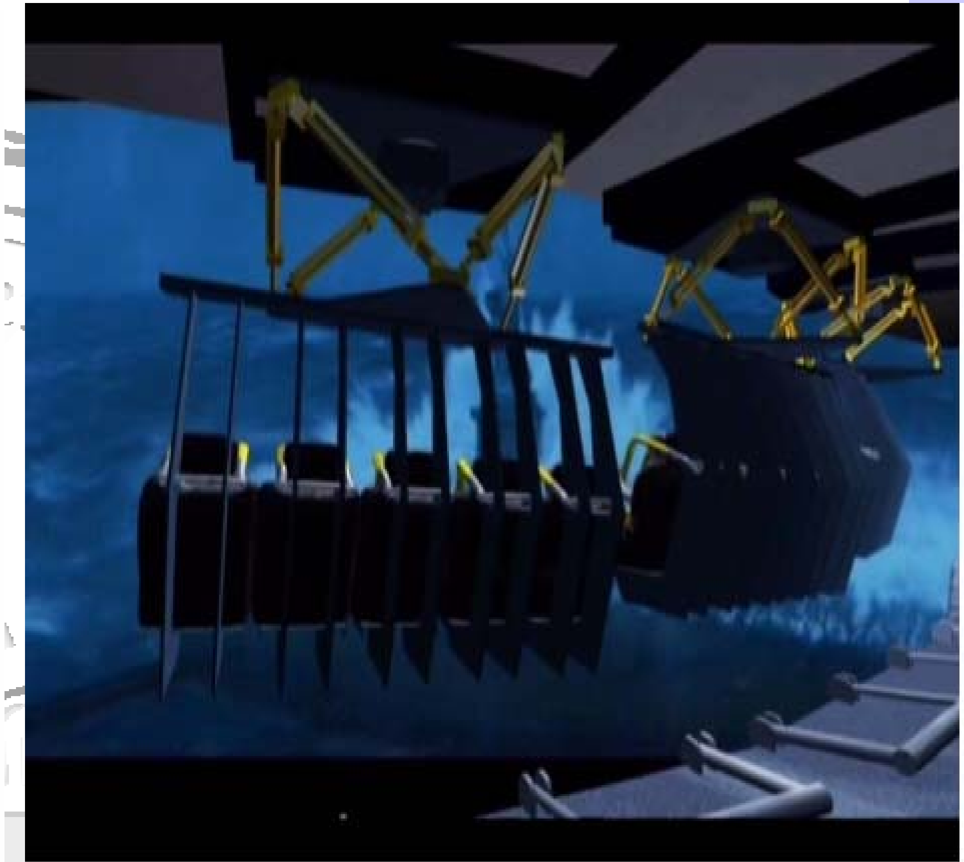
Taiwan Navy Boat Handling Simulator

Helicopter

Earthquake

Earthquake Survival Simulator

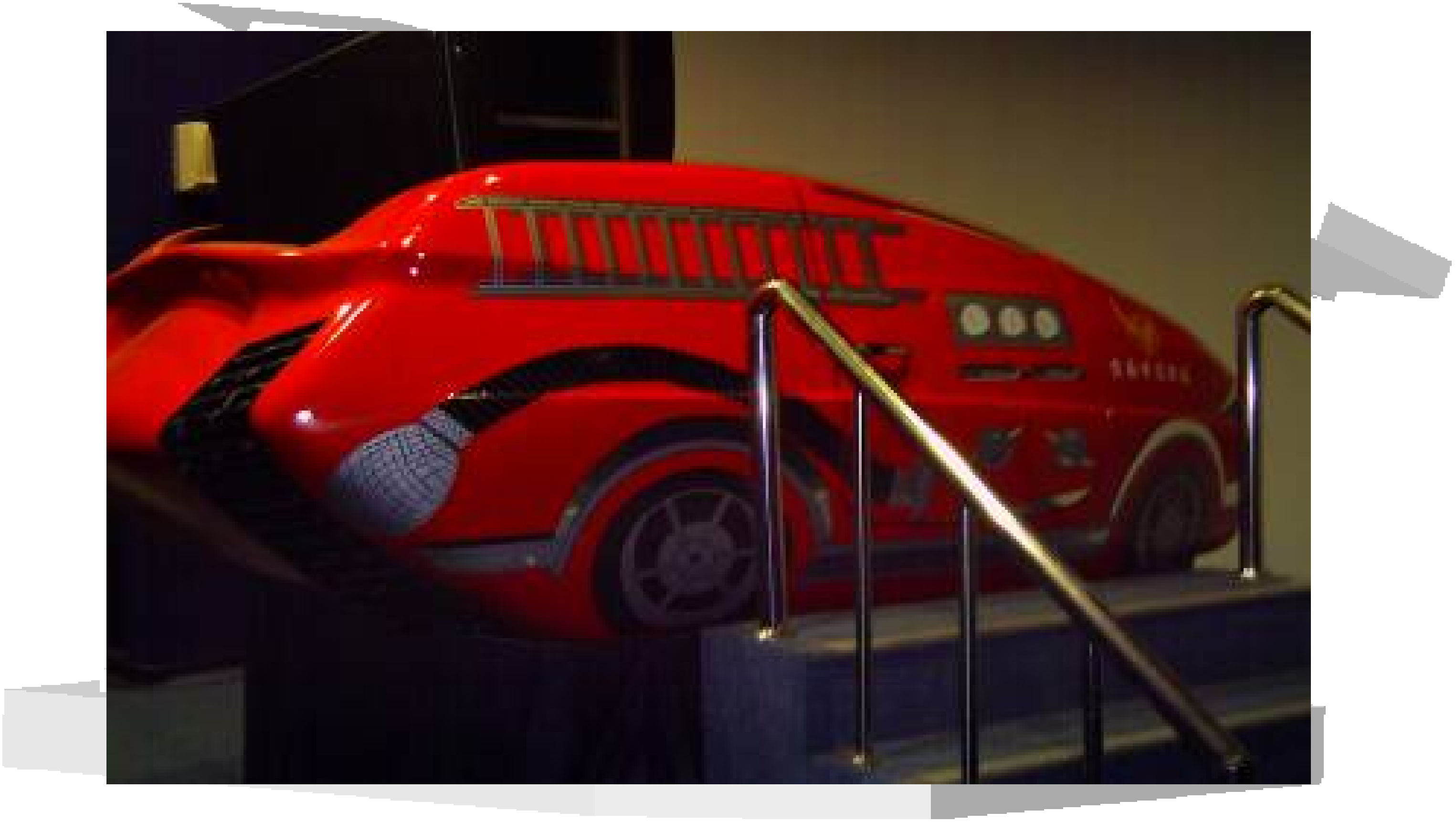
Entertainment



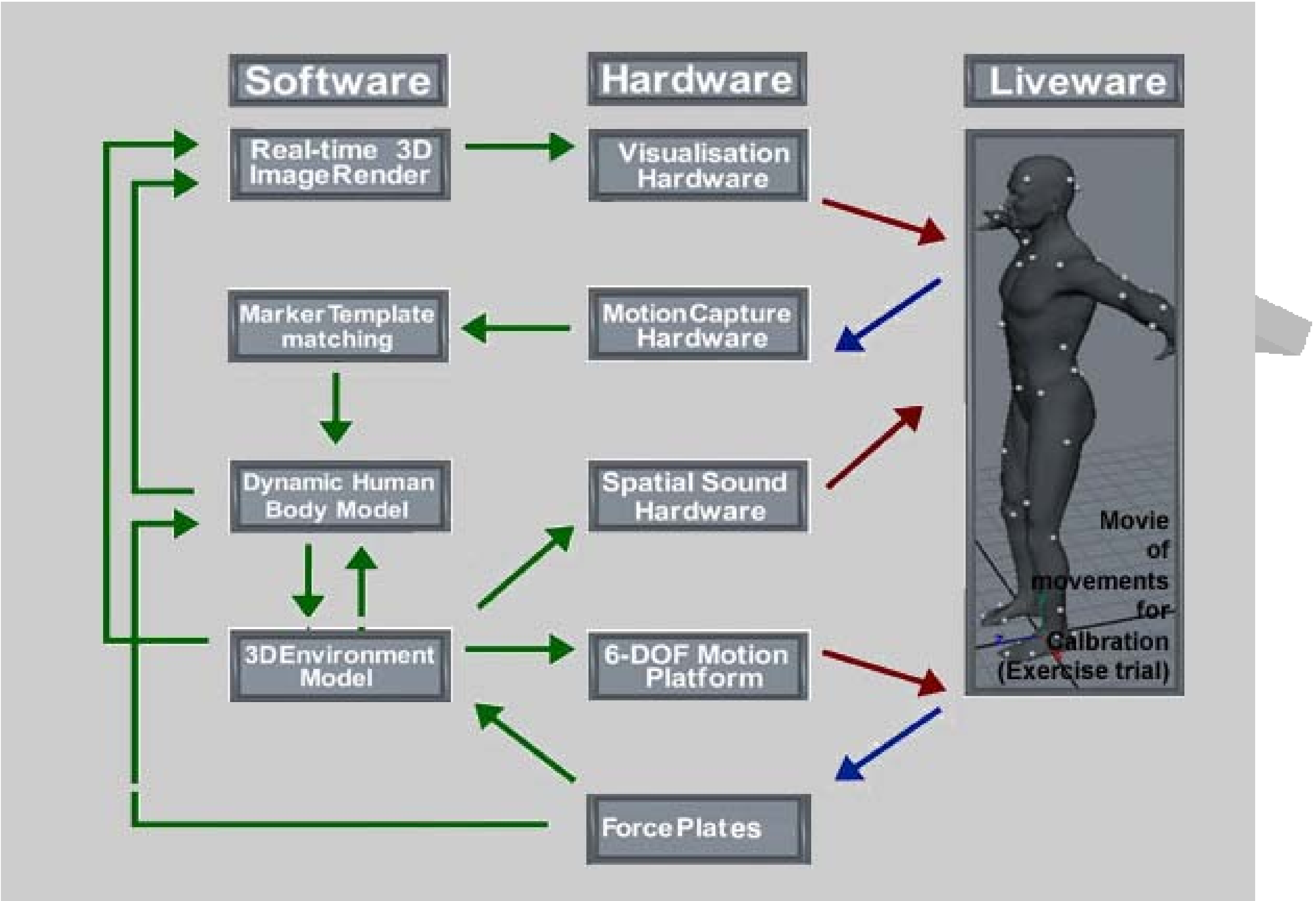
Flying House

4D Theater

Motion Theater



Medical

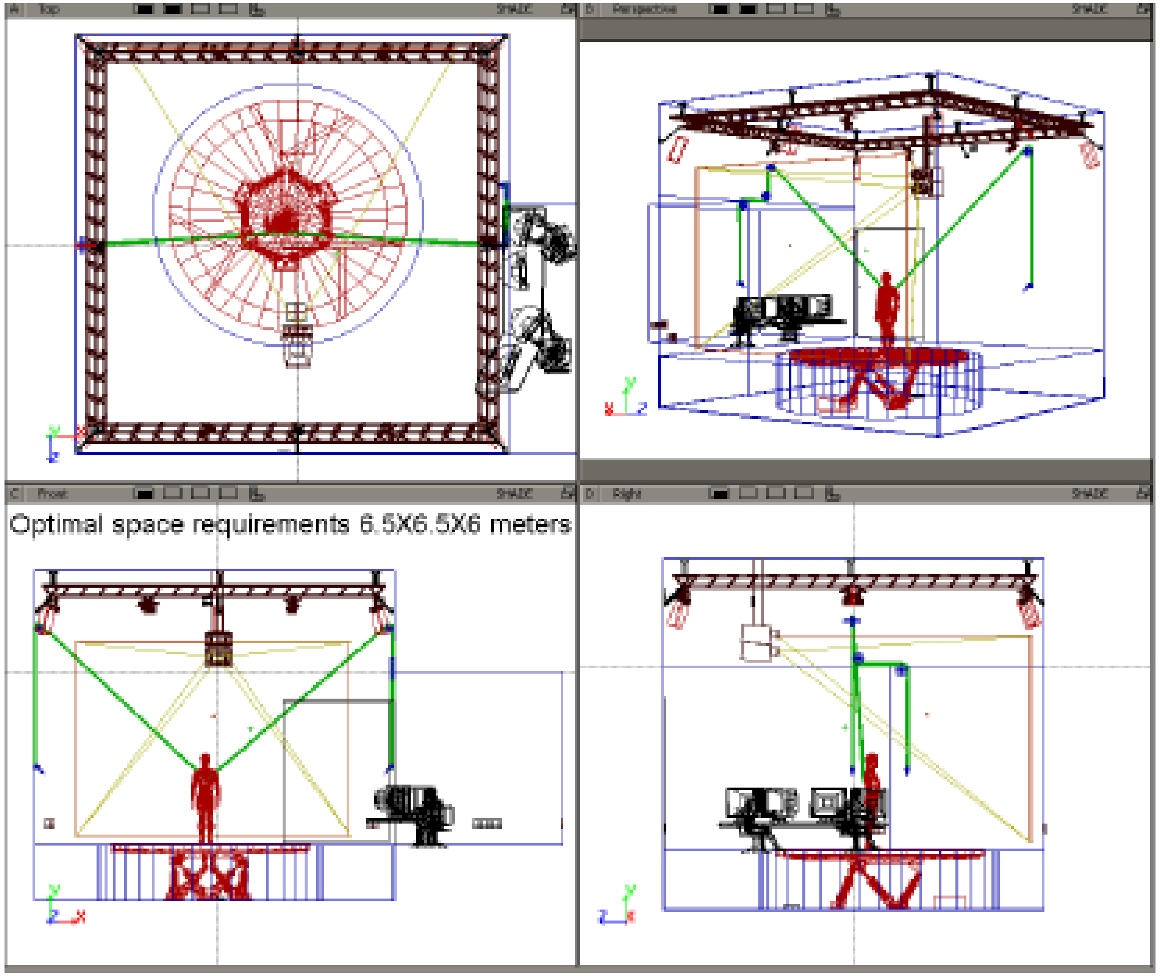

Software
Hardware
Liveware
Real-time 3D Image Render
Visualisation Hardware
Marker Template matching
Motion Capture Hardware
Dynamic Human Body Model
Spatial Sound Hardware
3D Environment Model
6-DOF Motion Platform
Force Plates
Movie of movements for Calbration (Exercise trial)

Assistant Tools

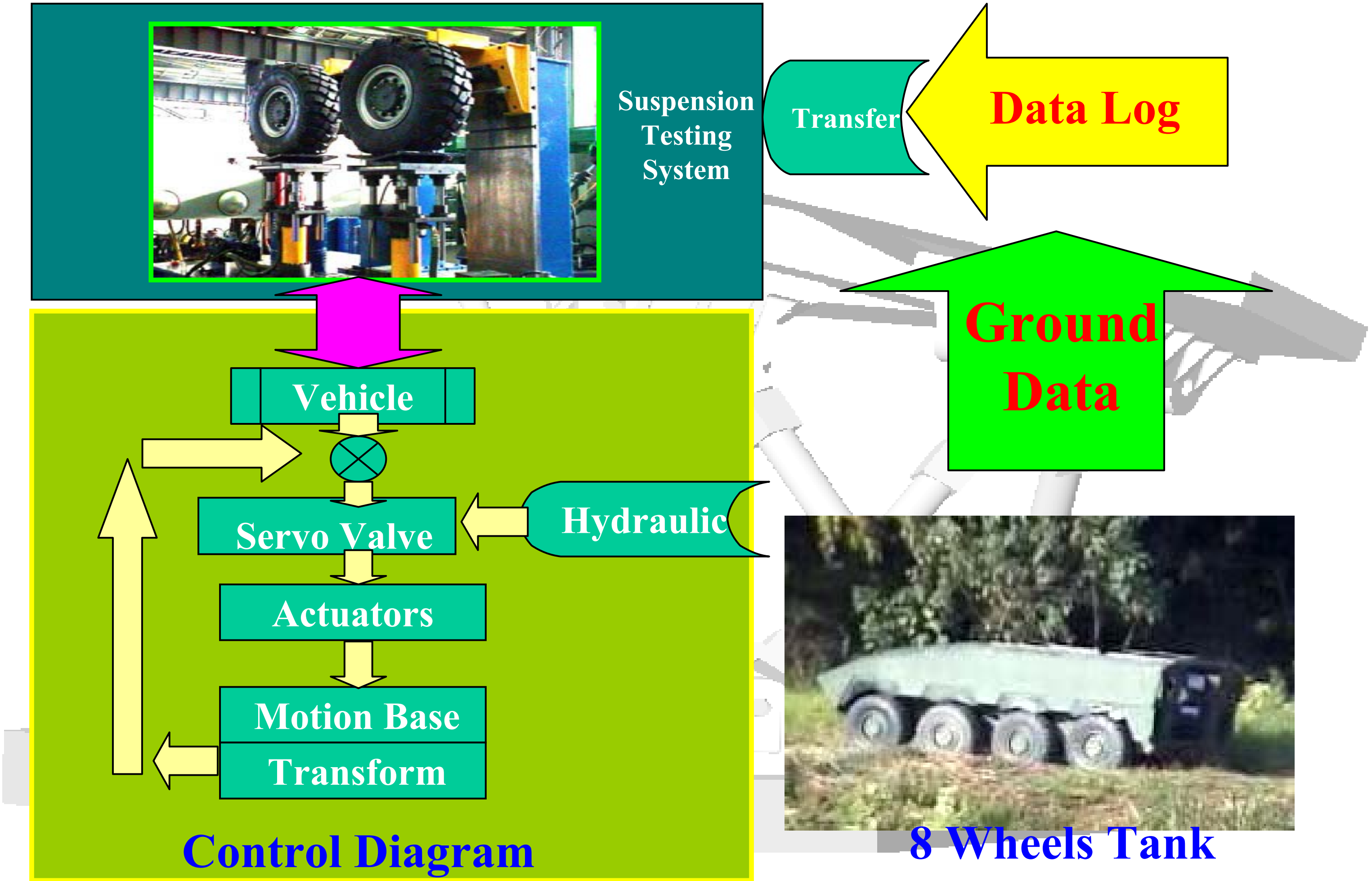
Figure 1. The Rutgers Mobility Simulator. © Rutgers University and UMDNJ. Reprinted by permission.

Power Assistant Wheel

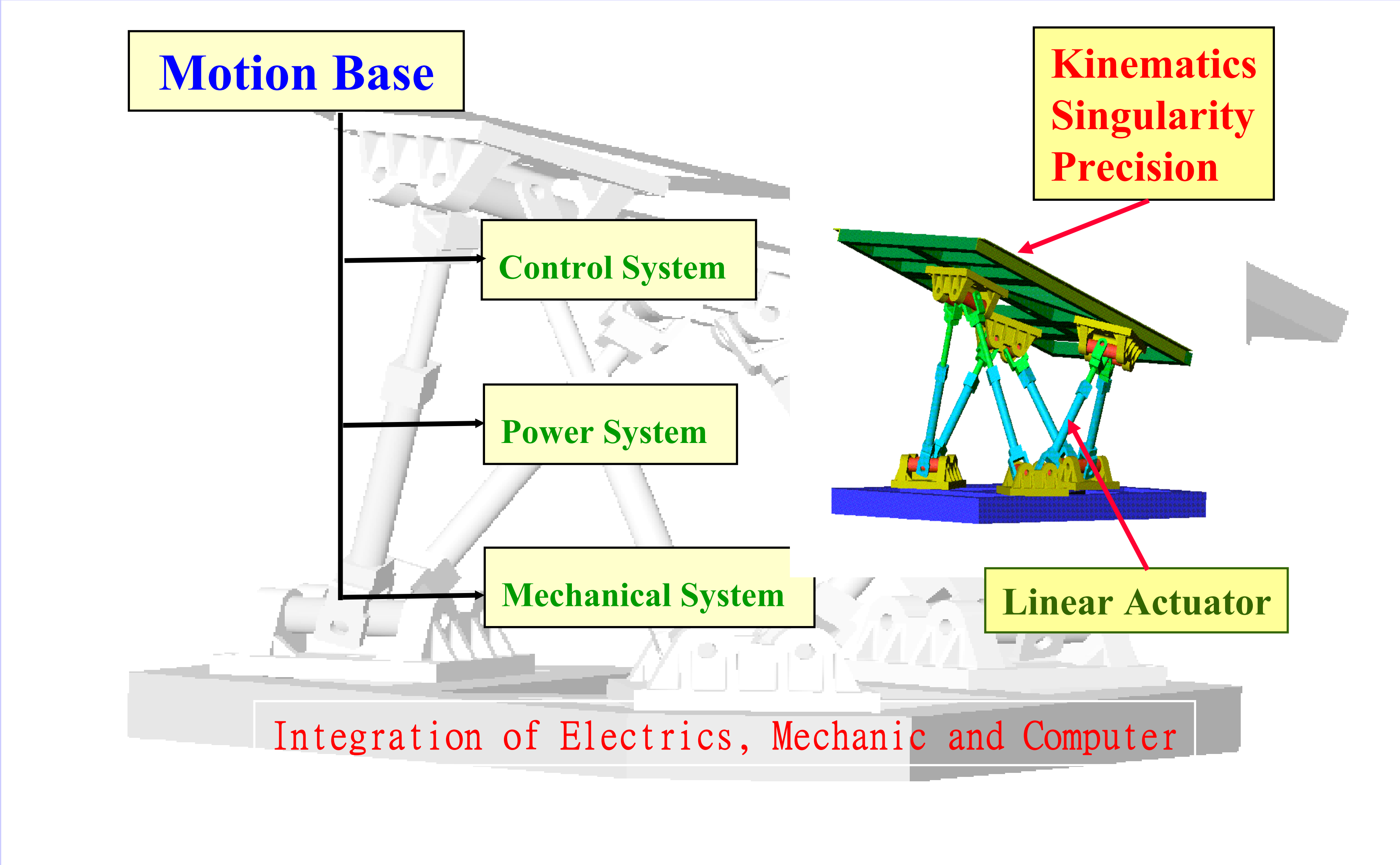
Human Performance



Engineering

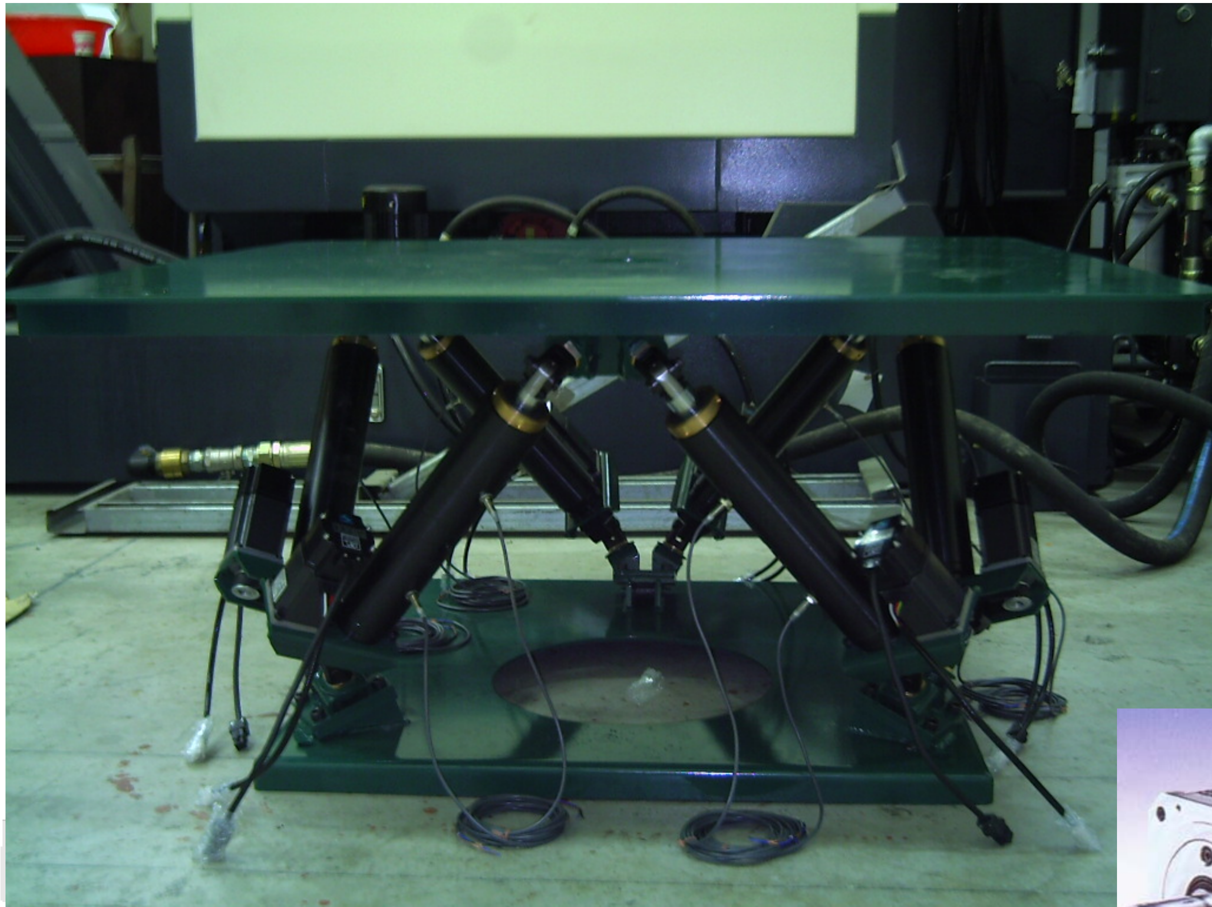


Motion Base Technology

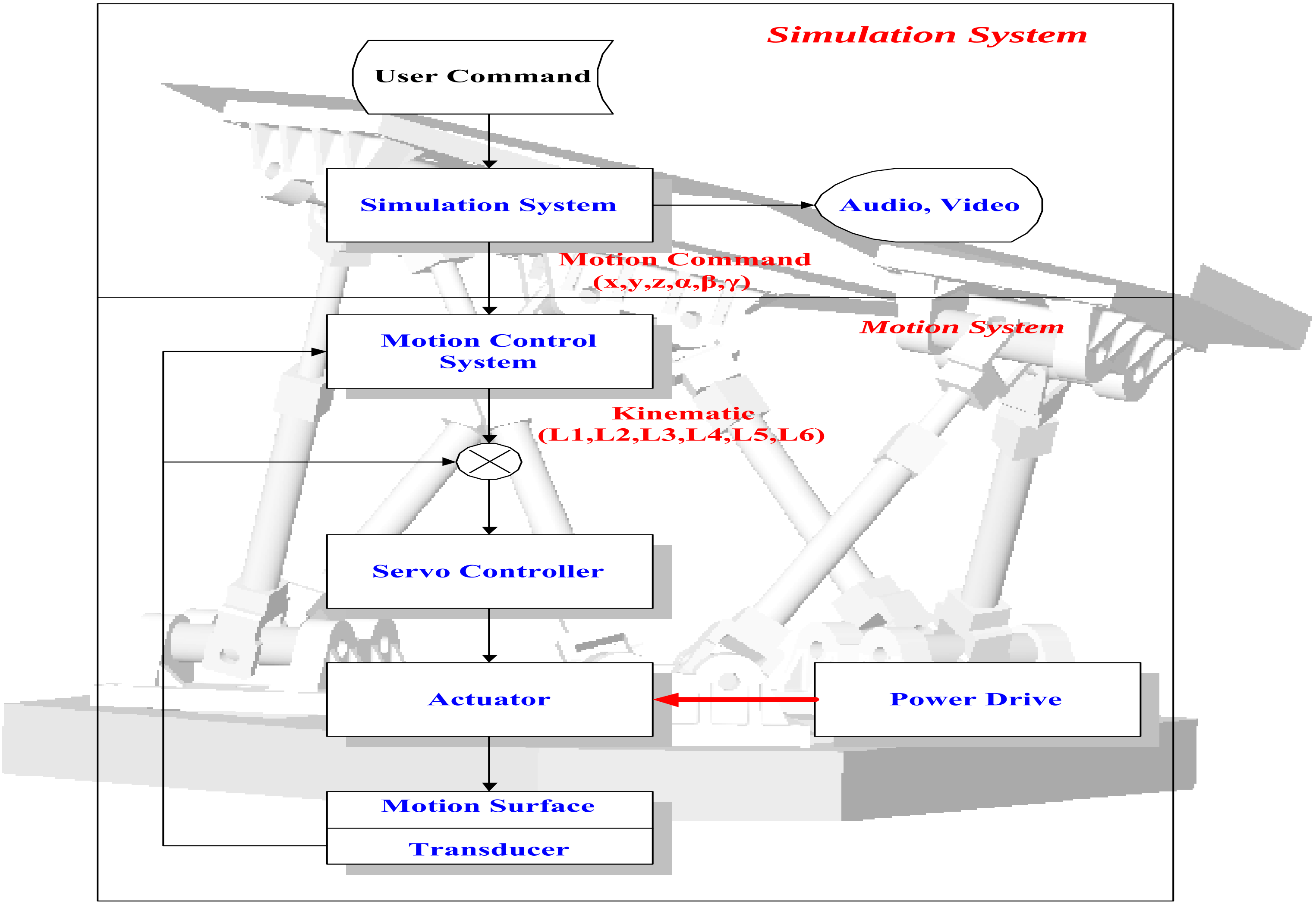


Hydraulic System

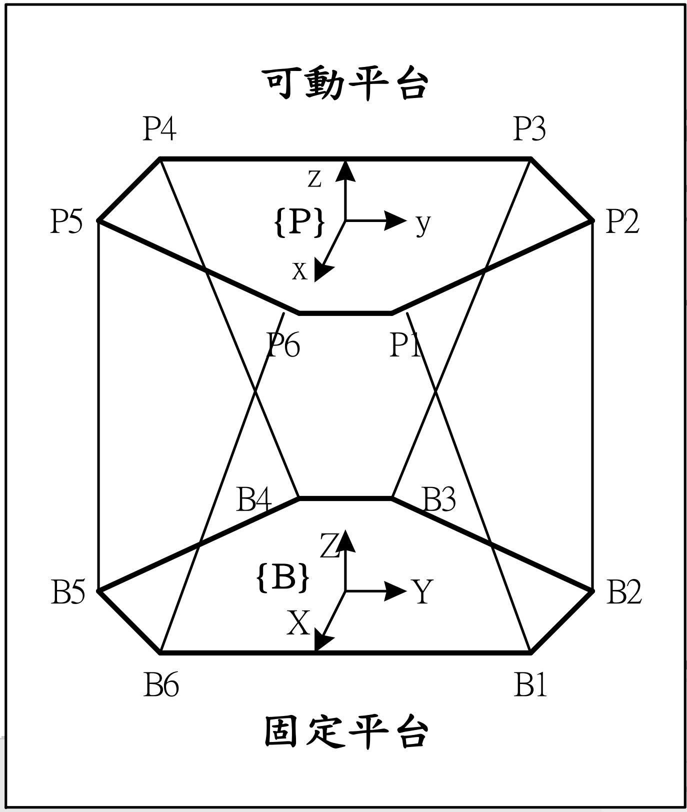
Electric System



Control Unit



Coordinate



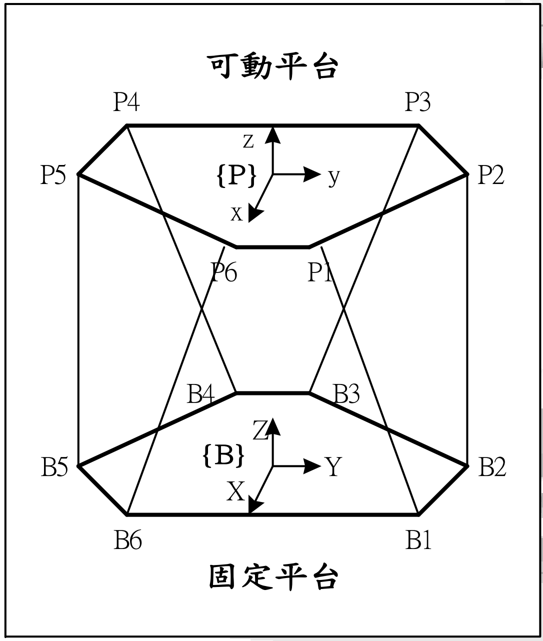
- Define two coordinate
  { P } Moving Platform、
  { B } Fixed Platform
- { B } →{ P }
  Movement (Surge, Sway, Heave)
  Rotation (Roll, Pitch, Yaw)

Inverse Kinematic

- 在已知可動平台位置姿態(x, y, z, α , β , γ)的情況下，各個致動器相對應的長度 Li 爲何。

$$S_i = R \bullet P_i + P - B_i$$

$$L_i = \| S_i \|$$



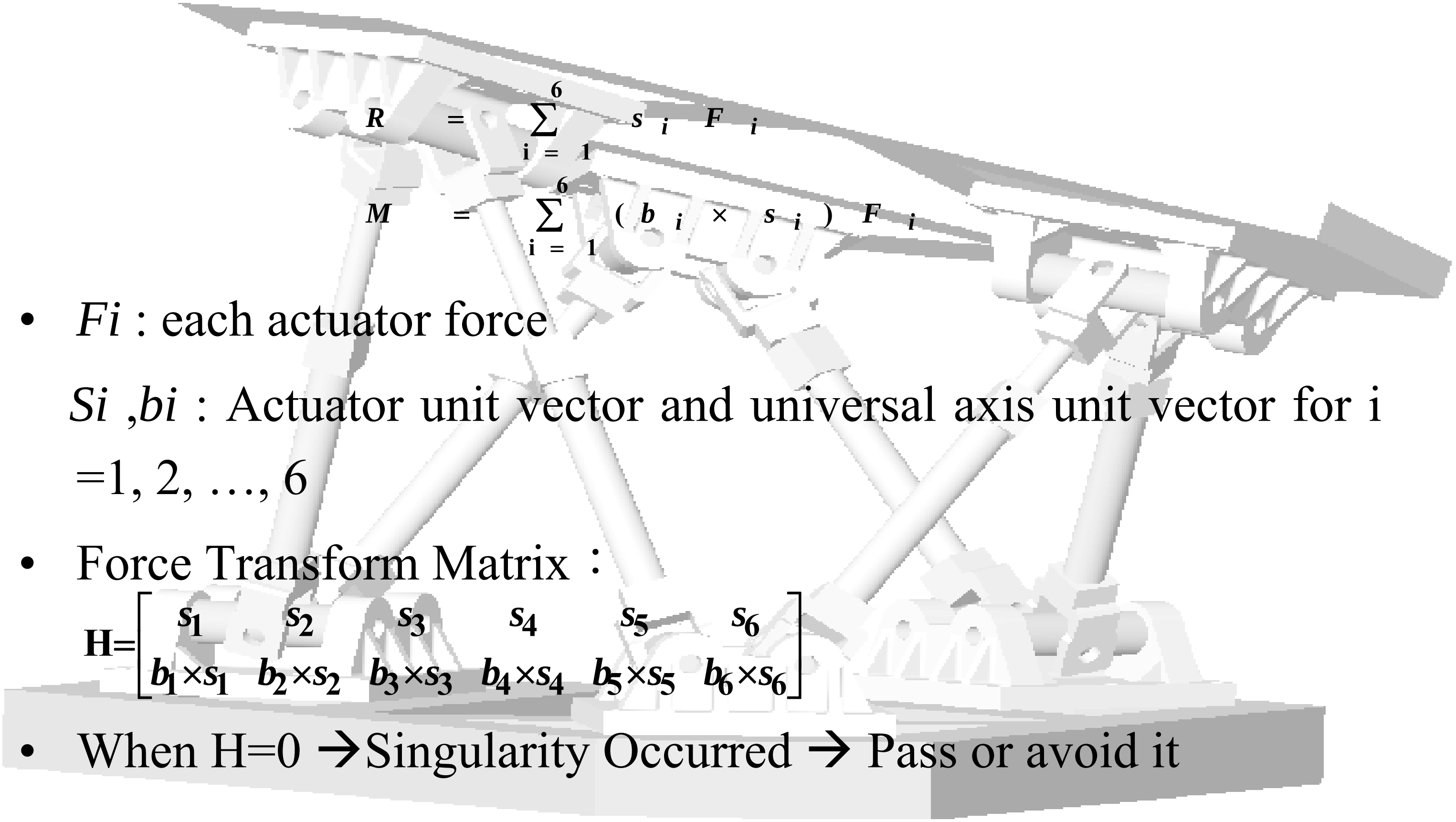
$$R=\begin{bmatrix} c\alpha & -s\alpha & 0 \\ s\alpha & c\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} c\beta & 0 & s\beta \\ 0 & 1 & 0 \\ -s\beta & 0 & c\beta \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 \\ 0 & c\gamma & -s\gamma \\ 0 & s\gamma & c\gamma \end{bmatrix}=\begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}$$

- 逆向運動學的完整解：

$$\begin{aligned} L_i^2 = {} & x^2 + y^2 + z^2 + r_p^2 + r_B^2 + 2(r_{11}p_{ix} + r_{12}p_{iy})(x - b_{ix}) \\ & + 2(r_{21}p_{ix} + r_{22}p_{iy})(y - b_{iy}) + 2(r_{31}p_{ix} + r_{32}p_{iy})z \\ & - 2(xb_{ix} + yb_{iy}) \end{aligned}$$

r_{ij} 爲旋轉矩陣R的元素，i, j = 1,2,3
r_B 和 r_P 爲固定平台與可動平台的半徑
(radii)

Singularity Analysis



- Sum of the Force and Moment :

$$R = \sum_{i=1}^{6} s_i F_i$$

$$M = \sum_{i=1}^{6} (b_i \times s_i) F_i$$

- *Fi* : each actuator force

  Si ,*bi* : Actuator unit vector and universal axis unit vector for i =1, 2, …, 6

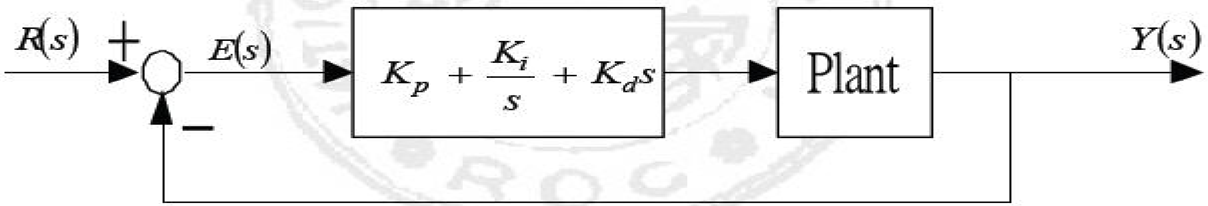
- Force Transform Matrix :

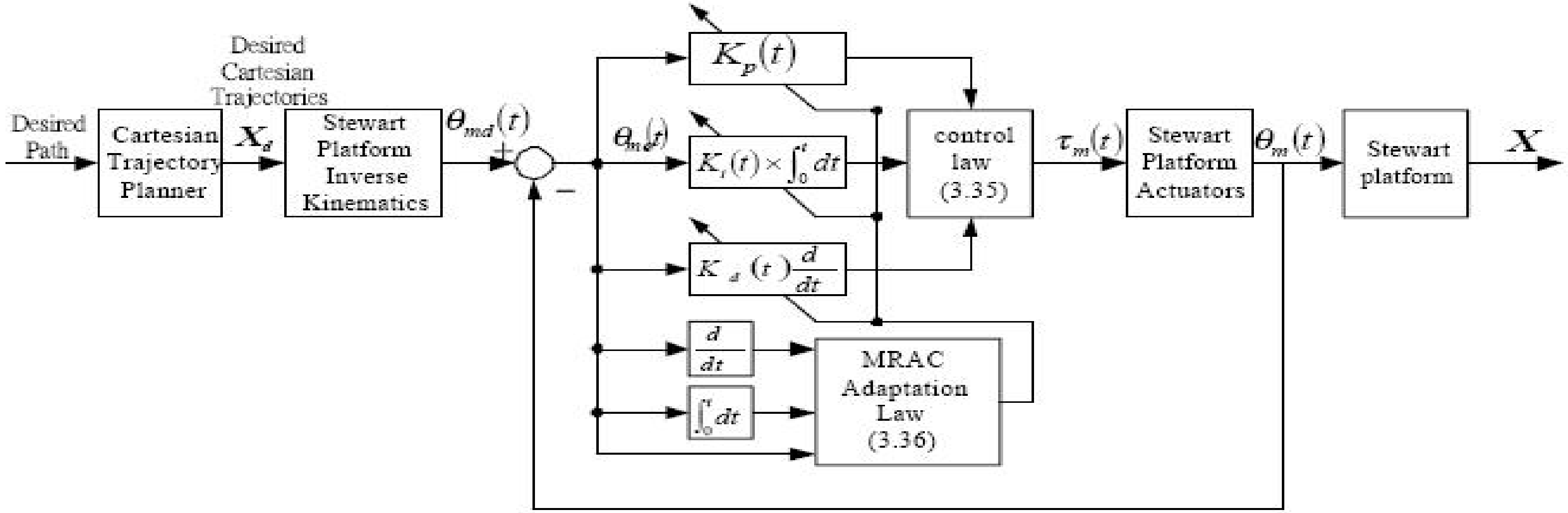
$$H = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 & s_5 & s_6 \\ b_1 \times s_1 & b_2 \times s_2 & b_3 \times s_3 & b_4 \times s_4 & b_5 \times s_5 & b_6 \times s_6 \end{bmatrix}$$

- When H=0 →Singularity Occurred → Pass or avoid it

PID

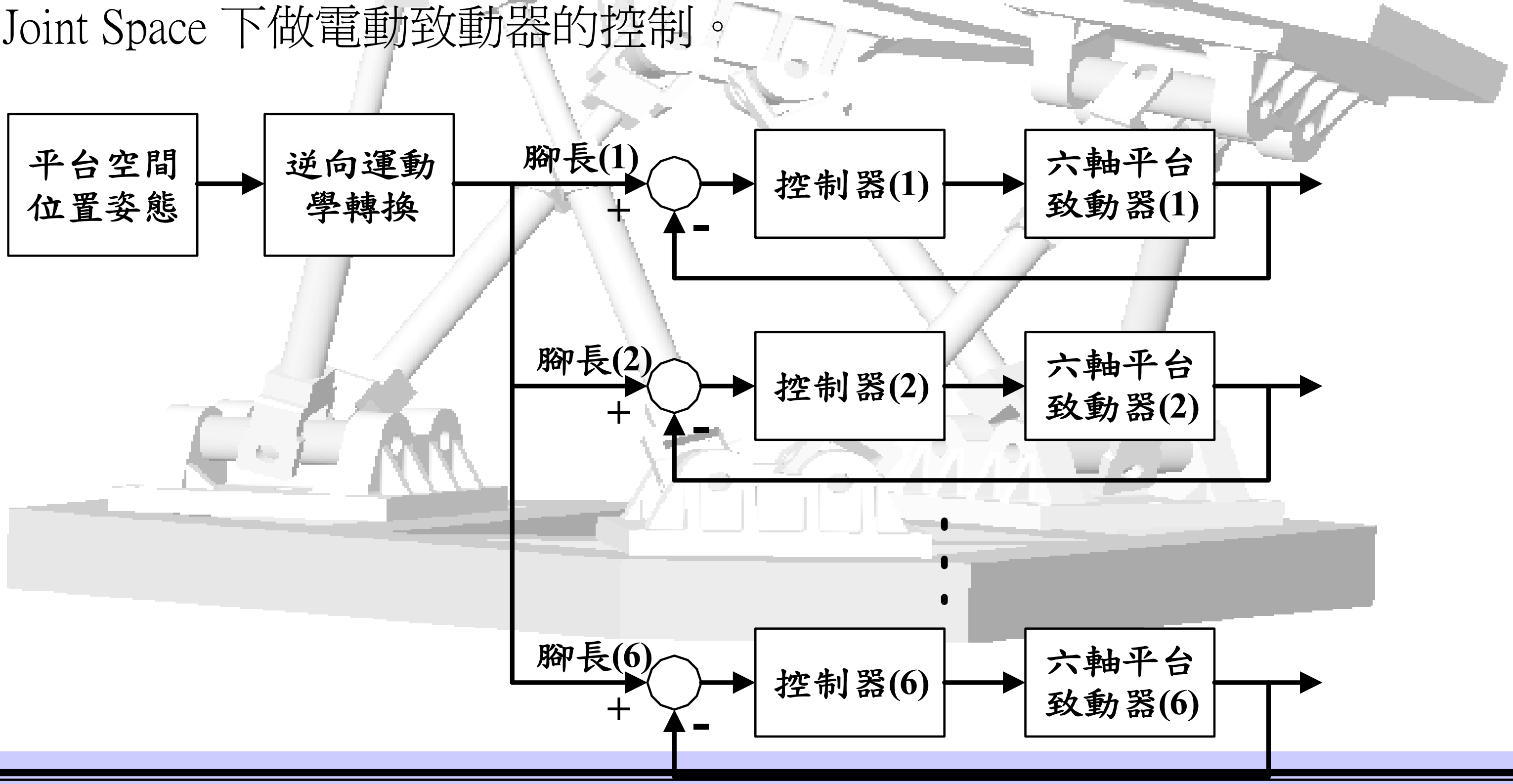
利用PID (比例控制、積分控制及微分控制)控制器的原理，經Inverse Kinematics所求得的腳長轉換爲電壓值驅動致動器上之驅動元件，讓致動器能來回運動。



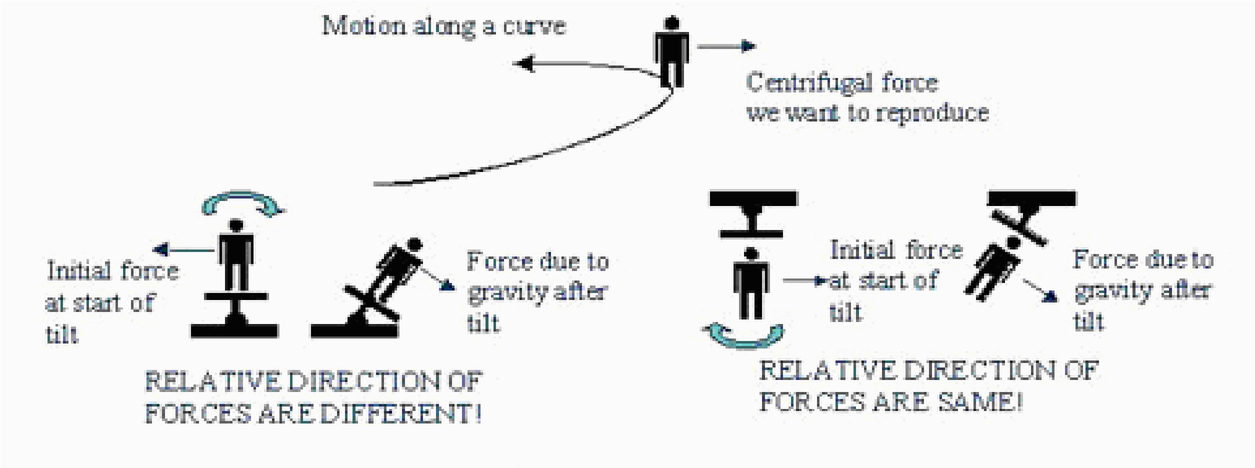


Control Flow

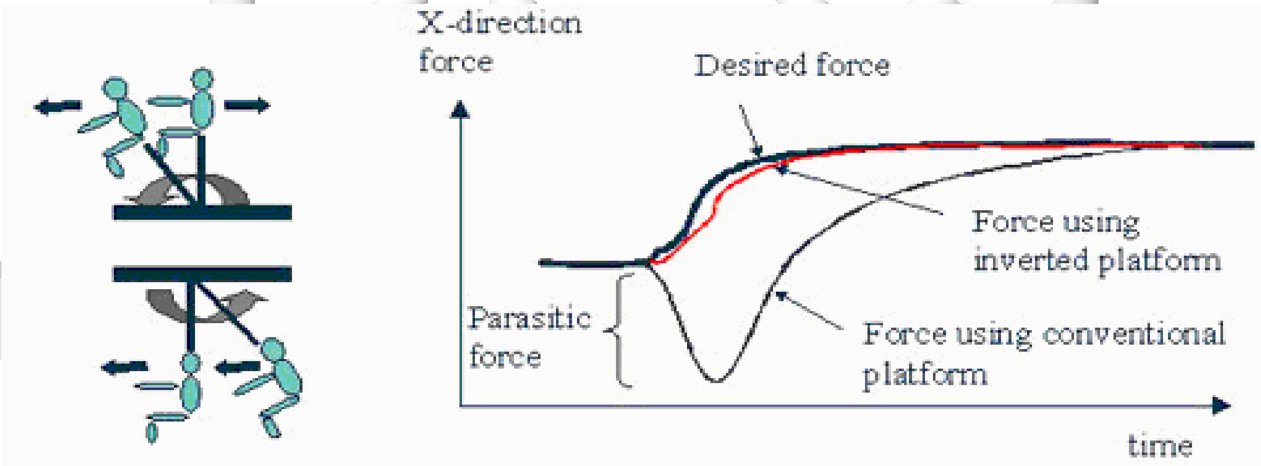
- 對六軸平台運動軌跡的描述是採用 Cartesian Space 表示， 即可動平台的位置姿態(x, y, z, α , β , γ)，經由逆向運動學的轉換得各個致動器所對應的長度，再透過控制器來控制各個致動器的長度，即我們實際是在 Joint Space 下做電動致動器的控制。



Motion Cues



<Fig 1: Forces during a turn>



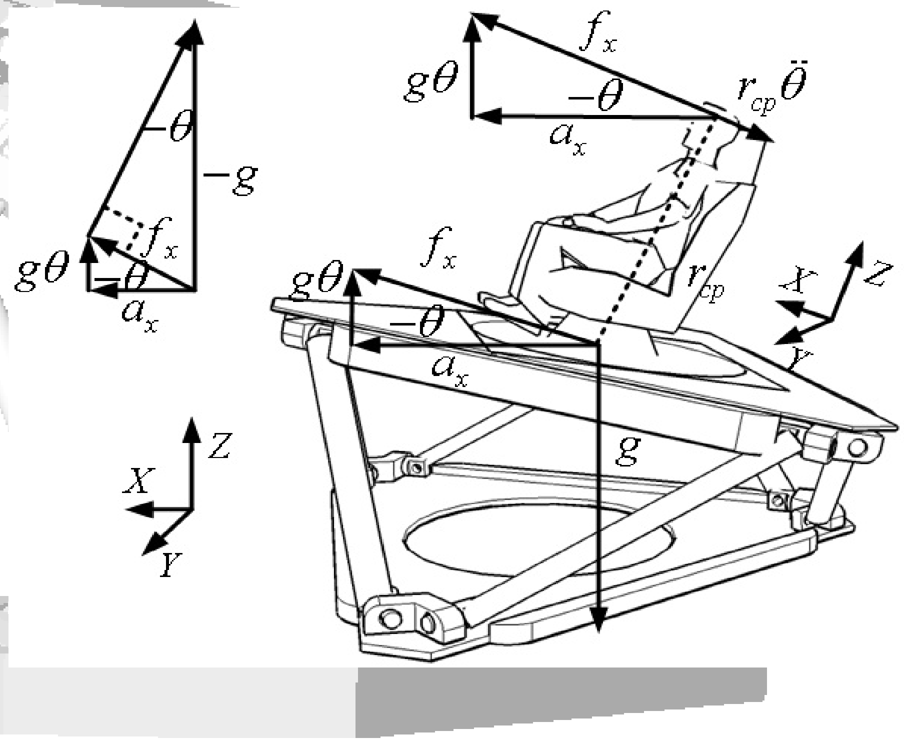
< Fig 2: Conventional and Inverted Platform Force Reproduction >

Washout Algorithm

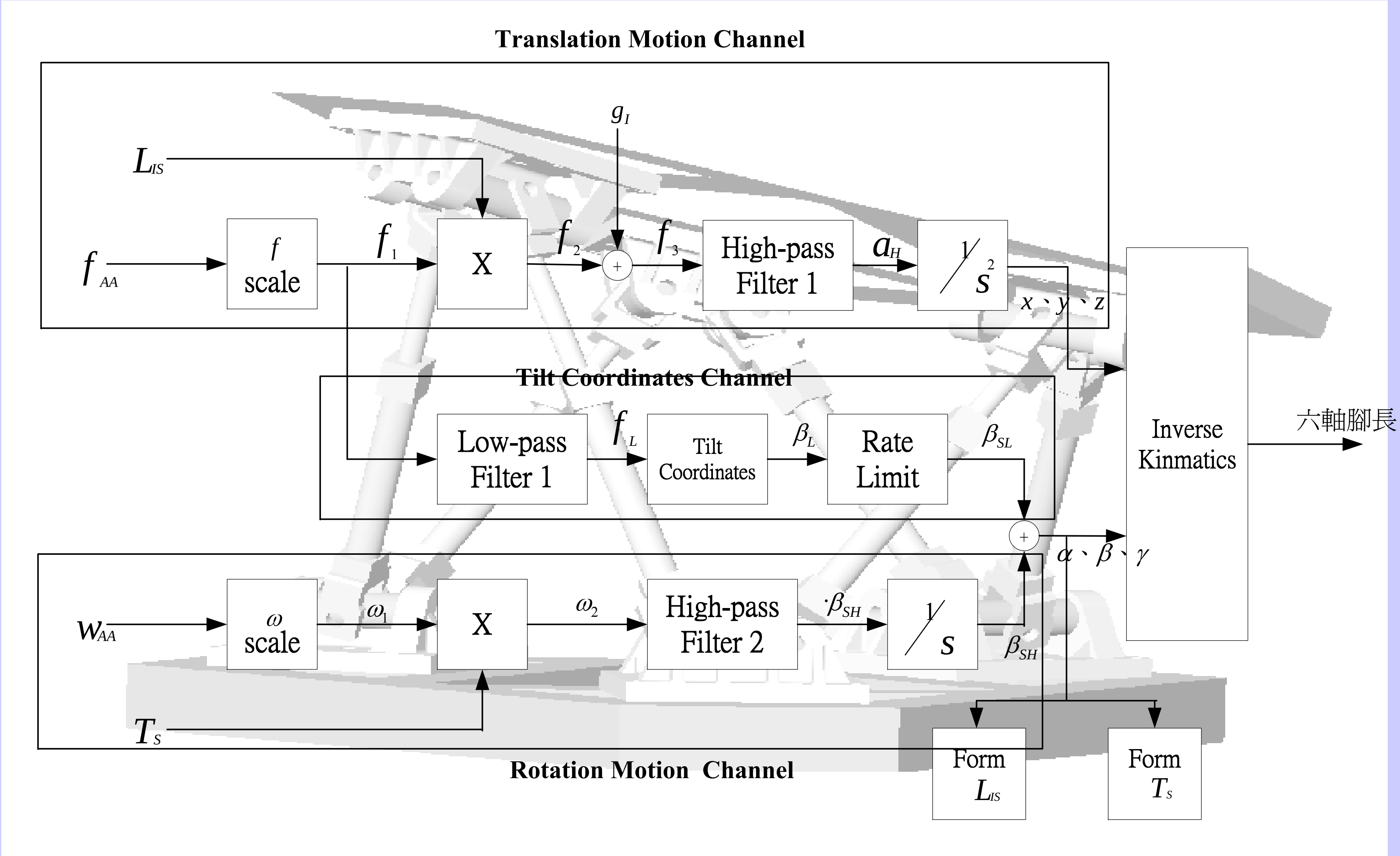
- “沖淡演算法(Washout Algorithm)” 其實是一種概念：

(1) 它主要是利用人類對感覺具有門檻值(Threshold Value)的特性，適當地將某些頻率成分的線性運動或轉動加以濾除。

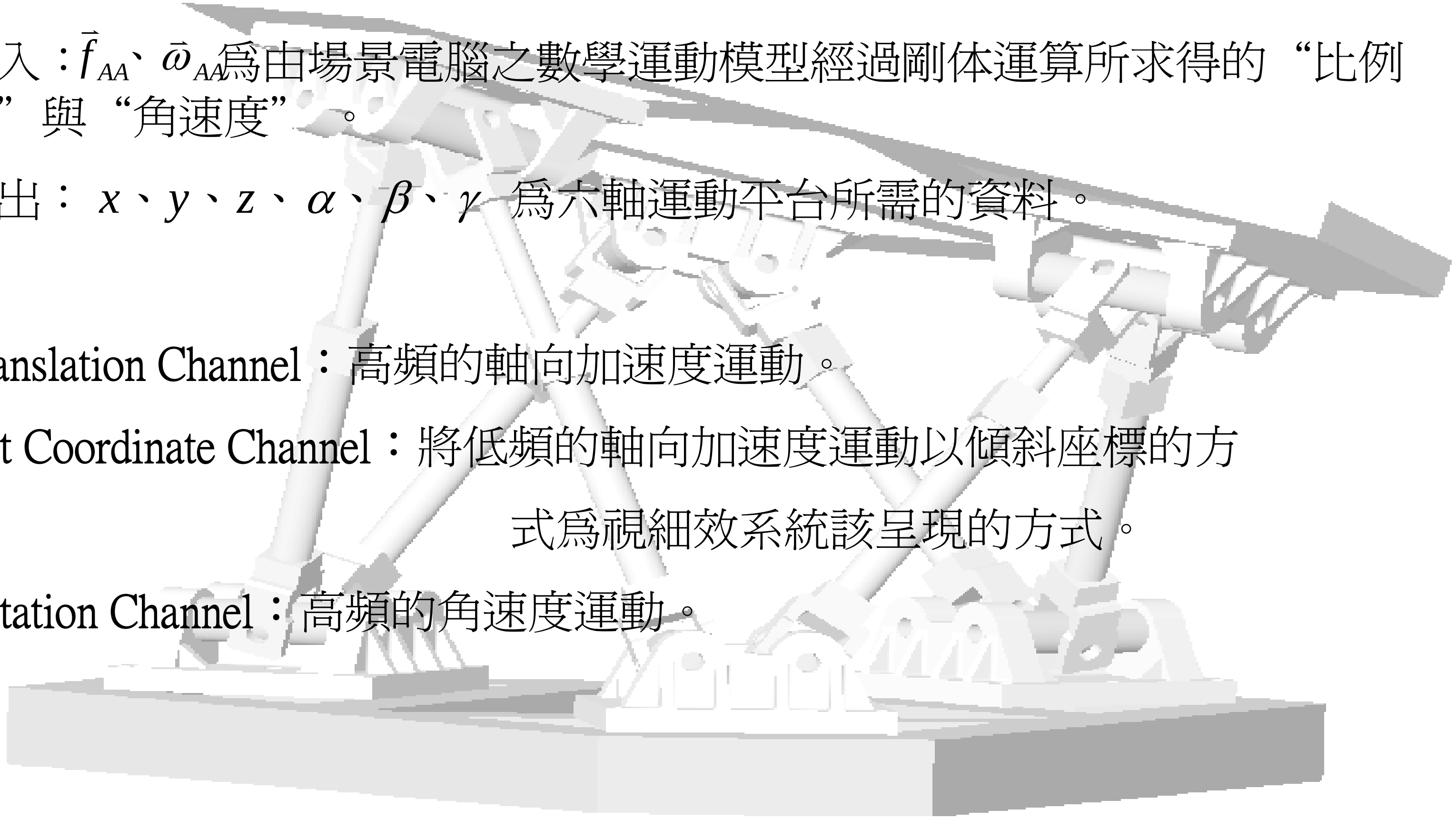
(2) 並將持續的比例力感覺用緩慢轉動一傾斜角的方式來實現，這些轉動被控制在人類對轉動感覺的門檻值以下，操作員將不會有明顯的感覺，以避免混淆原本的轉動運動的感受。



Structure


Translation Motion Channel
L_{IS}
g_I
f_{AA}
f scale
f_1
X
f_2
f_3
High-pass Filter 1
a_H
$1/s^2$
x、y、z
Tilt Coordinates Channel
Low-pass Filter 1
f_L
Tilt Coordinates
β_L
Rate Limit
β_{SL}
Inverse Kinmatics
六軸腳長
α、β、γ
w_{AA}
ω scale
ω_1
X
ω_2
High-pass Filter 2
$\dot{\beta}_{SH}$
$1/s$
β_{SH}
T_S
Rotation Motion Channel
Form L_{IS}
Form T_s

Explanation



輸入：$\vec{f}_{AA}$、$\vec{\omega}_{AA}$爲由場景電腦之數學運動模型經過剛体運算所求得的“比例力”與“角速度”。

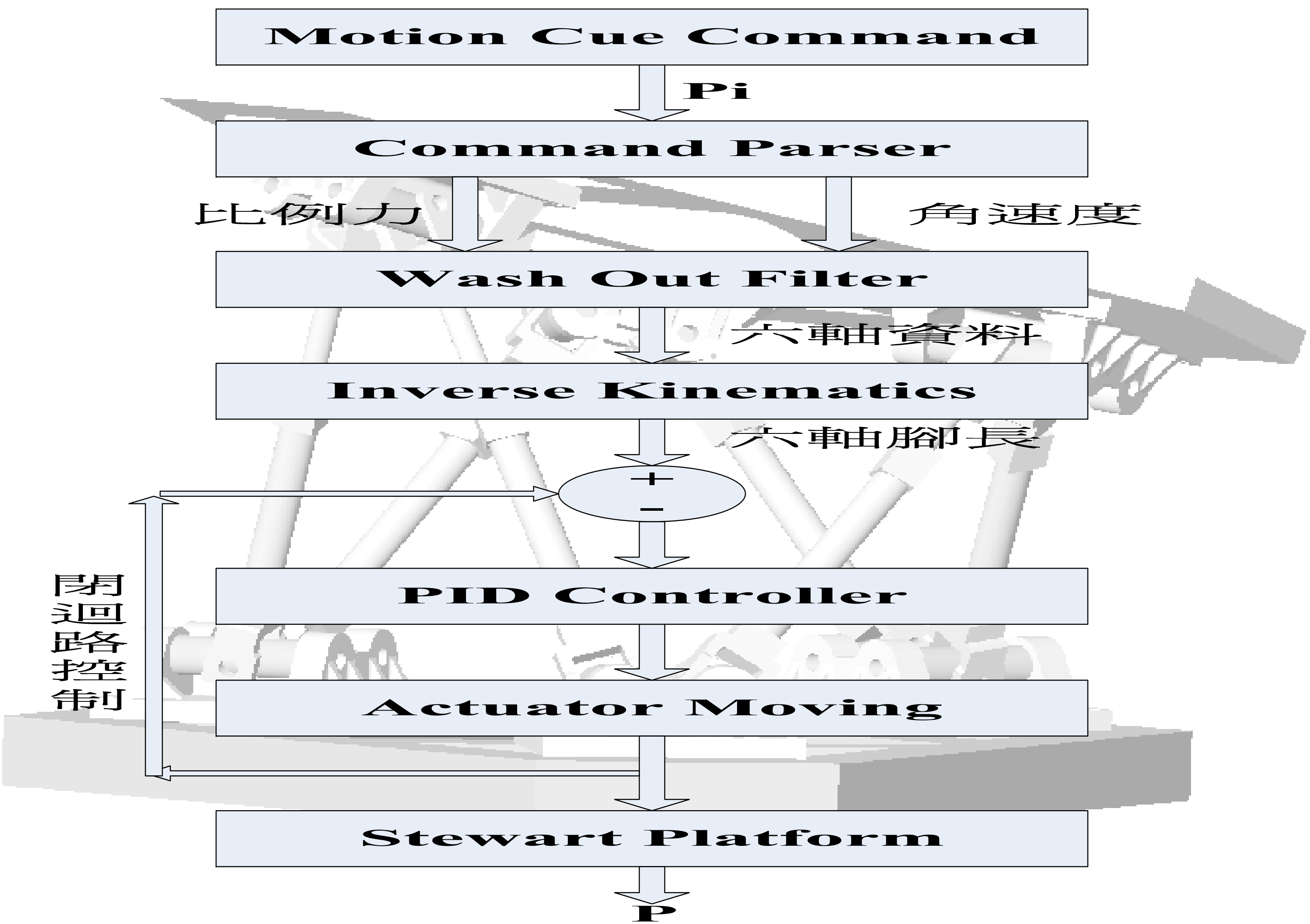
輸出：x、y、z、α、β、γ 爲六軸運動平台所需的資料。

Translation Channel：高頻的軸向加速度運動。

Tilt Coordinate Channel：將低頻的軸向加速度運動以傾斜座標的方式爲視細效系統該呈現的方式。

Rotation Channel：高頻的角速度運動。

Motion System Driven Flow (I)



Motion System Driven Flow (II)

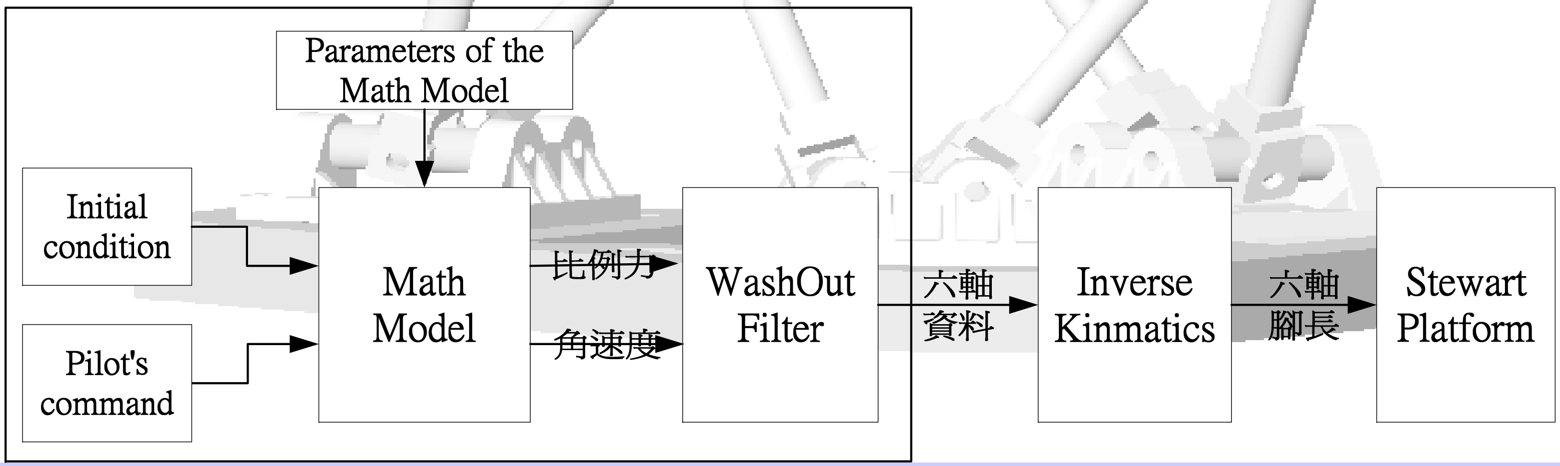
1.Initial Condition：爲系統所予模擬的運動器一開始的初始狀態。

2.Pilot’ s Command：爲操作者對模擬器所發出的操作命令，經轉換後如直線加速度或角速度等命令。

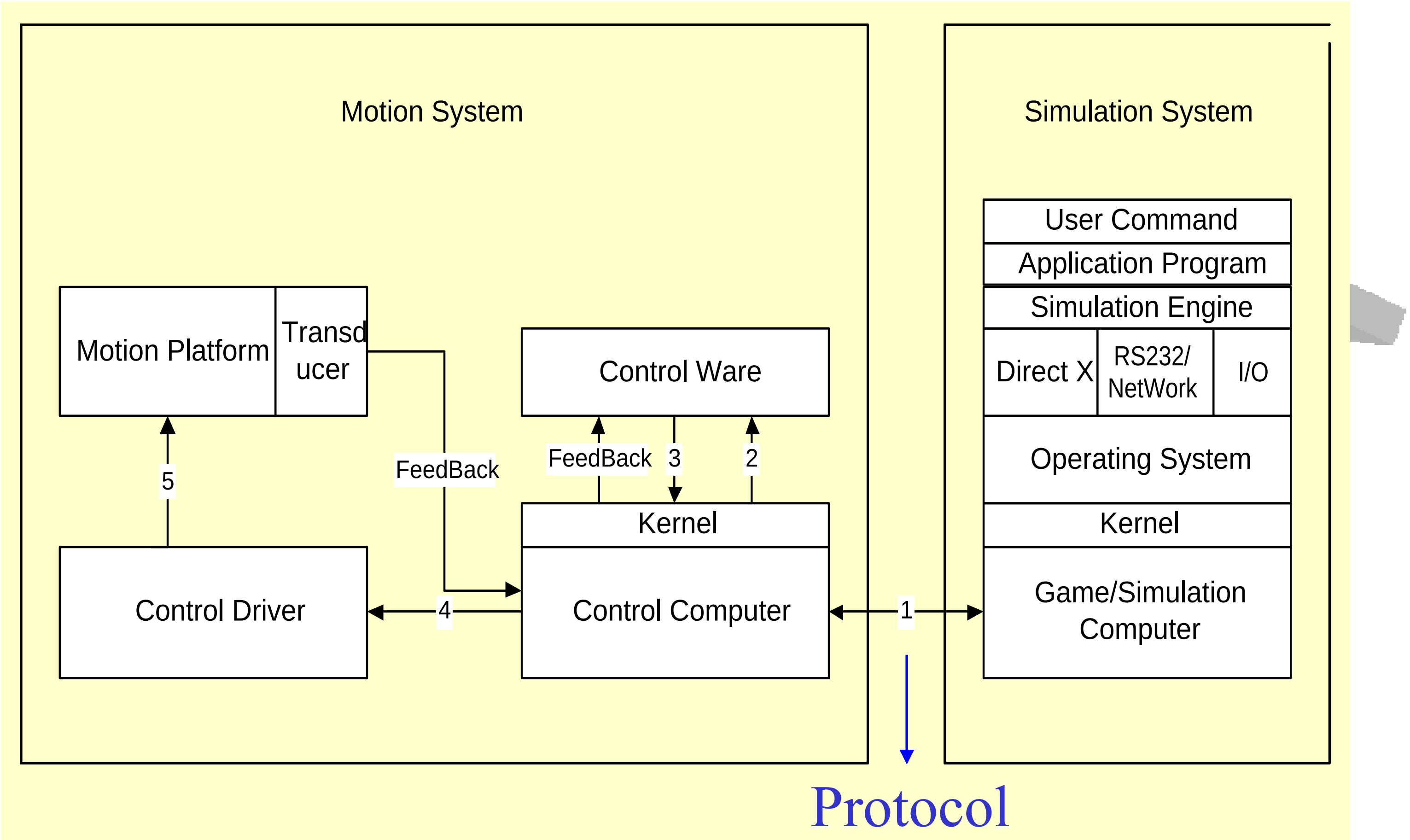
3.Parameters：模擬器的運動器的參數，如交通工具的質量、引擎參數等參數。

4.Math Model：依此數學運動模型求出模擬器上駕駛員的受力情形。

5.Washout Filter：包含三大部份(1)平移運動(Translation Motion) (2)轉動運動(Rotation Motion) (3)傾斜座標(Tilt Coordinate)，以此架構將模擬器上之任一參考點之運動轉換爲其在上平台對應點之運動。

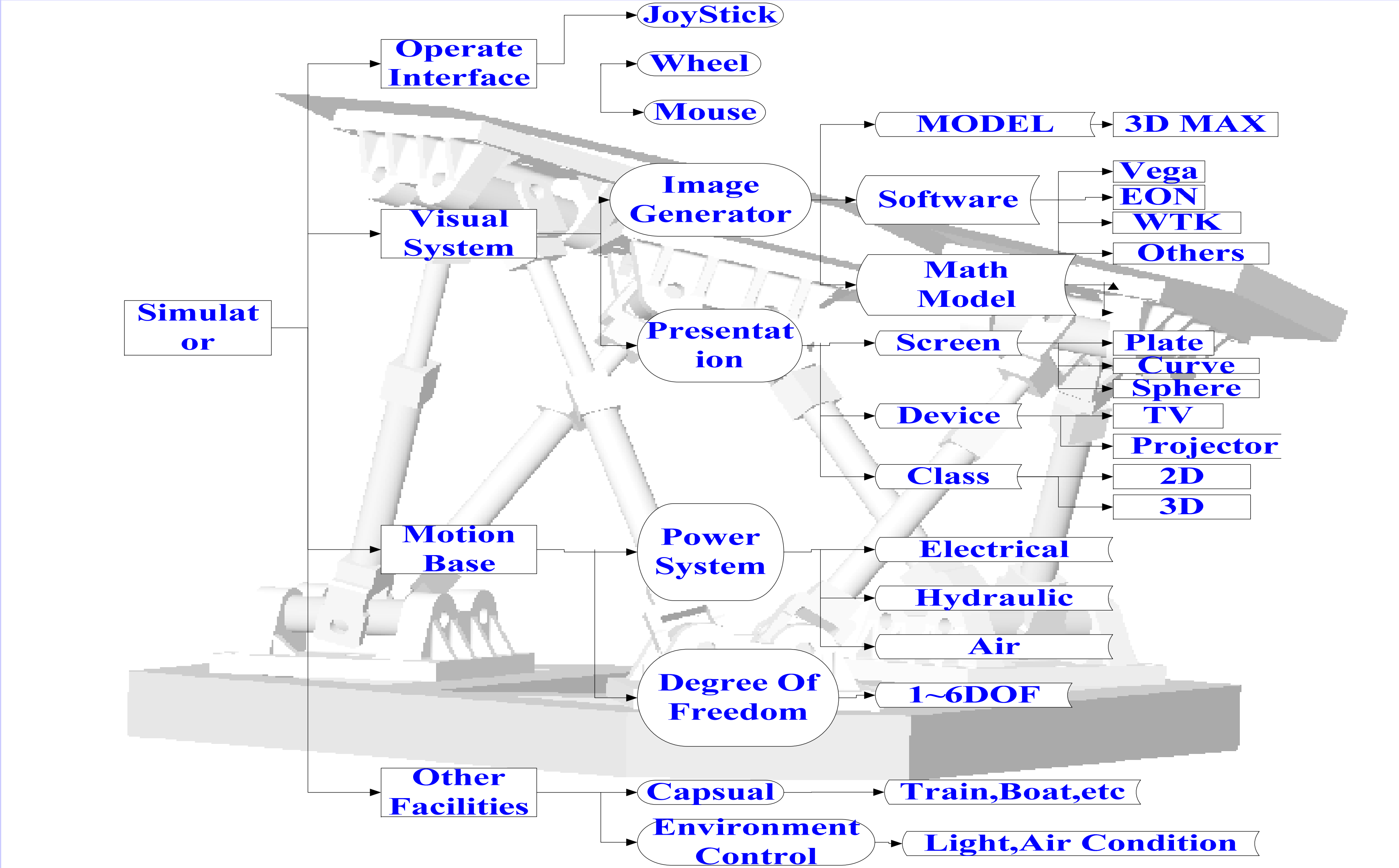


Relation Map



影像模 擬系統 與 動作平台系統關 連圖

Simulator Structure



Horner

核心價質

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安全　品質　歡笑

Thank You!

Q & A