Digital Human Simulation (DHS) for Physical User Interface Design

포항공과대학교
산업경영공학과

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Agenda

- **Physical User Interface Design**
  - Definition
  - PUI: Subcategory of UI
  - Importance of UI Design
- **Digital Human Simulation**
  - Definition & Benefits
  - History
  - Architecture
  - Design Process with DHS
  - Design Applications

Physical User Interface Design

- ✓ Definition
- ✓ Types of UI
- ✓ Importance

User Interface?

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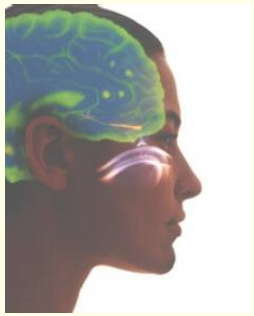
- **Definition**

  The device, method, or modality used to accommodate the interaction between the system (consumer product, machine, tool, software, or document) and the user.

Types of User Interface



Physical Interface

Cognitive Interface

Emotional Interface

UI Design Issues: Automobile Interior

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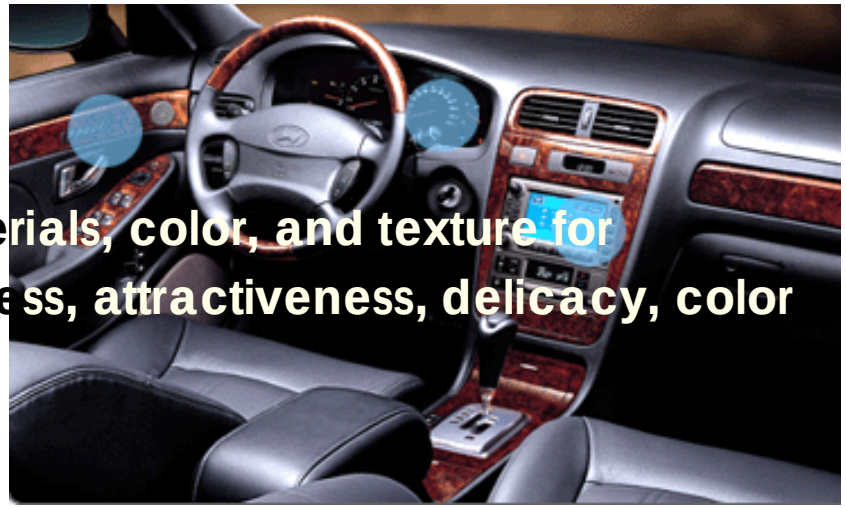
- **Physical UI**
  - Positioning and sizing seats, controls, and mirrors for reach, visibility, and accessibility
  - Designing seats for comfort and habitability
- **Cognitive UI**
  - Designing gauges, displays, and navigation systems for information processing time, accuracy, ease of use, and ease of learning
- **Emotional UI**
  - Designing configuration, materials, color, and texture for emotional appeal (luxuriousness, attractiveness, delicacy, color feeling, harmony)



Importance of UI Design

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- Ease of use
- Ease of learning (training)
- Fitness
- Comfort
- Convenience
- Performance (time, accuracy, quality)
- Safety (error- or mistake-proof)
- Satisfaction
- Health

- Market competitiveness
- Profitability

Digital Human Simulation

- ✓ Definition & Benefits
- ✓ History
- ✓ Architecture
- ✓ Design Process with DHS
- ✓ Design Applications

Digital Human Simulation?

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- **Definition**

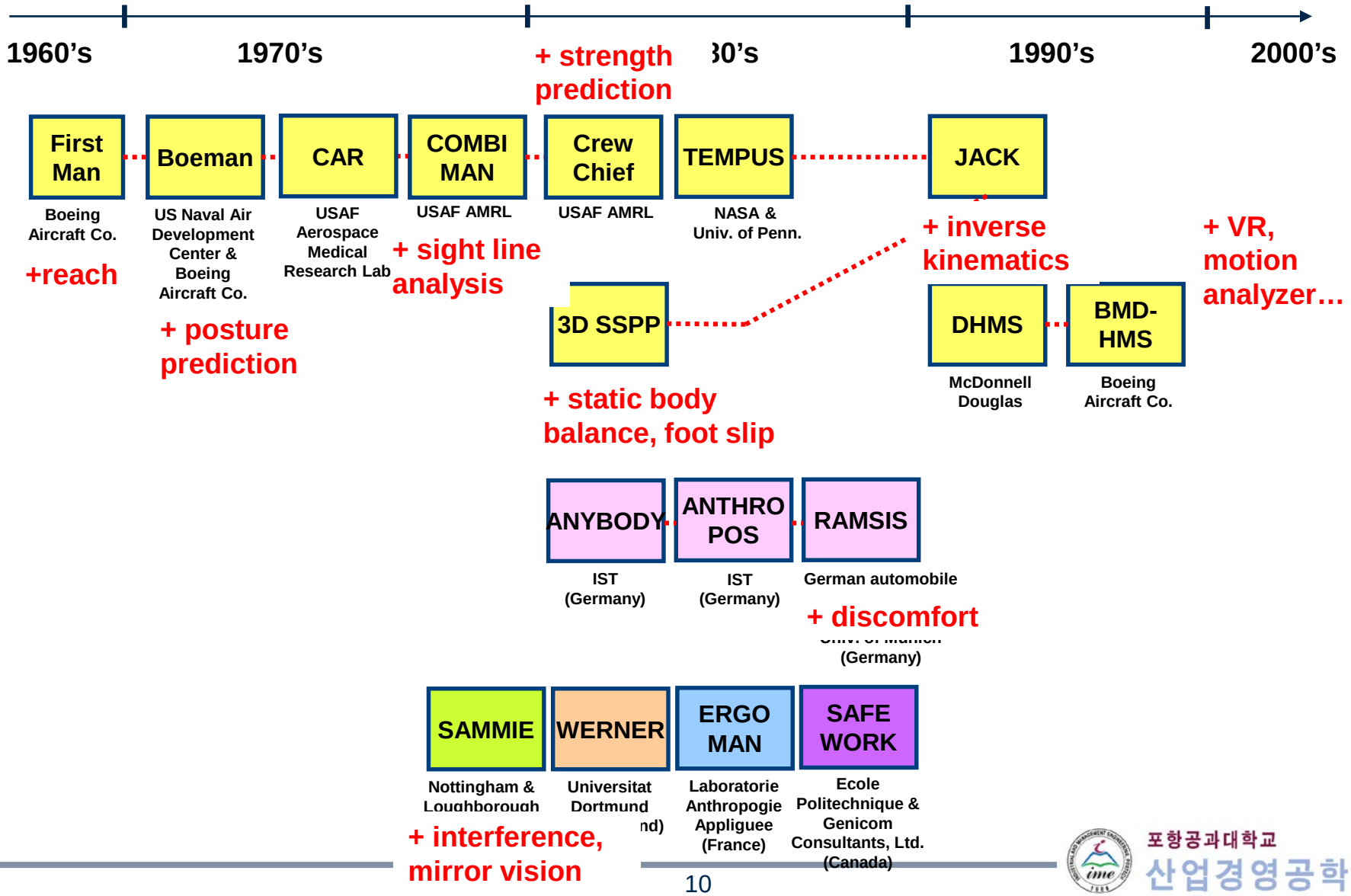
  Predicting the performance capabilities of designated groups of people within a computer rendered environment (Chaffin, 2001)

- **Benefits**
  - Earlier introduction of ergonomics into the design process
  - Increased safety, user satisfaction, productivity
  - Enhanced accommodation of the target population
  - Improved product quality
  - Reduced the number of physical prototypes
  - Shorter design time
  - Accelerated time to market
  - Lower development costs

Ergonomic Design Quality

Development Time & Cost

Brief History of DHS Systems



Architecture of DHS System

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Modeling

Human Modeling
- Anthropometry
- Representative humanoids
- Size estimation
- Skin
- Clothing

Performance Modeling
- Posture prediction
- Motion prediction
- Strength models
- Vision models

Task Animation
- Goals
- Scenario (posture & motion control timing)

Analysis & Optimization

Ergonomic Analysis
- Accessibility
- Visibility
- Reach
- Posture
- Biomechanical load
- Accommodation

Optimization
- Design diagnosis
- Design sensitivity
- Optimization algorithm

Interface

Virtual Prototyping
- CAD interface (import/export)
- Object creation/ manipulation

VR Interface
- Motion capture system
- Head mounted display
- Haptic devices

Design Process w/ DHS: Cockpit Design w/ RAMSIS

Capabilities of DHS Systems

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- Clearance (accessibility)
- Visibility
- Reach
- Posture
- Biomechanical/physiological load (strength, moment/torque, compressive force, energy expenditure, comfort, fatigue)

- Accommodation
- Virtual reality interface
- Specialized design functions (SAE design guidelines)

Design Application: Accessibility

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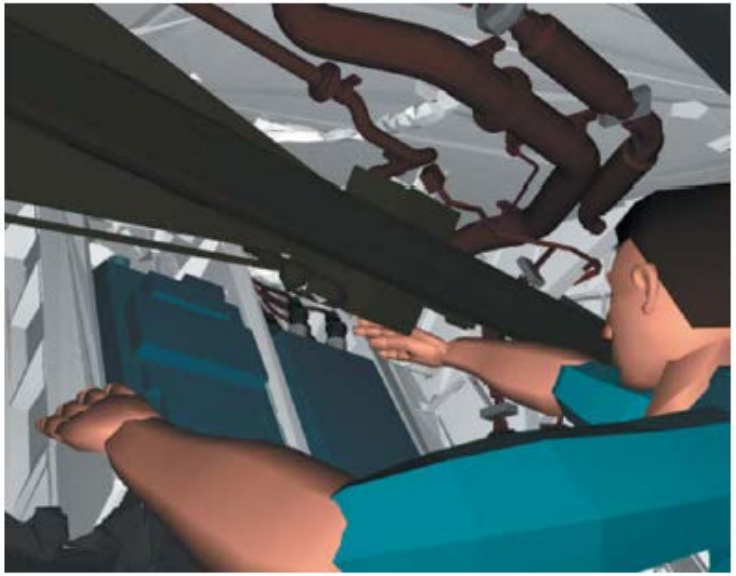
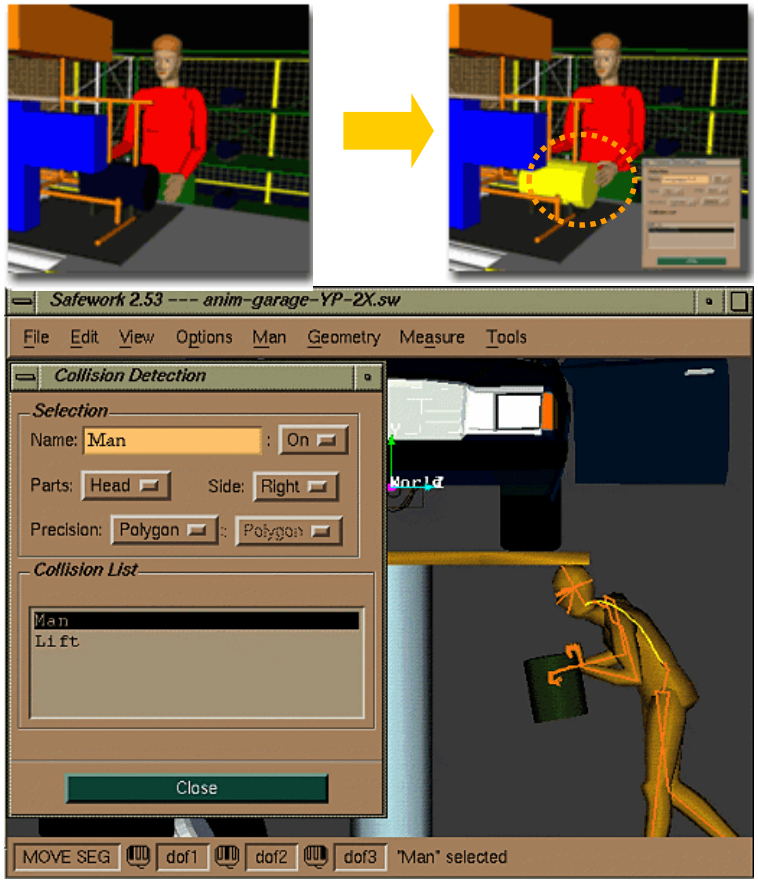
- **Evaluating clearance for the user to access an object, workspace, or system.**



F-22 aircraft maintenance task (removal of an avionics component from the aircraft's weapons bay)



Using collision detection algorithm

Design Application: Accessibility - KHP

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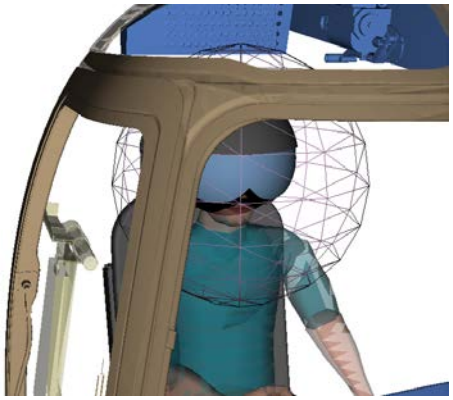
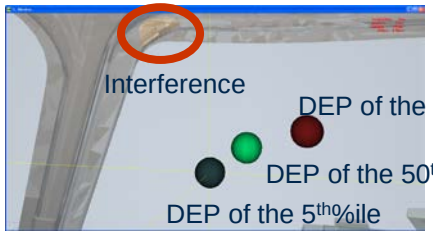
- 기본조종자세에서 머리와 조종석 동체의 여유공간(MIL-STD: 254 mm from DEP) 분석
  - 5th %ile: 252 mm
  - 50th %ile: 253 mm
  - 95th %ile: 258 mm

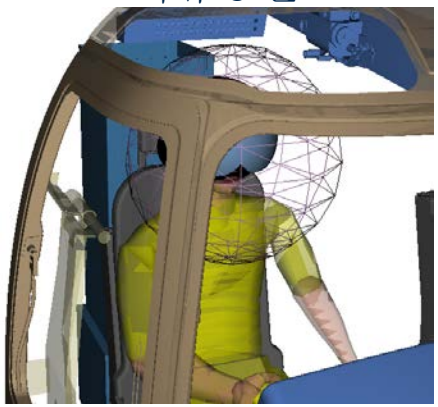
} MIL-STD 미 충족: 여유공간(2 mm)을 위해 door 설계 변경 예정

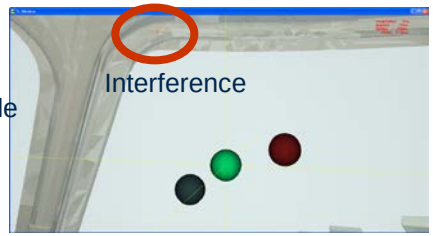
5th 대표인체모델
여유공간: 252 mm



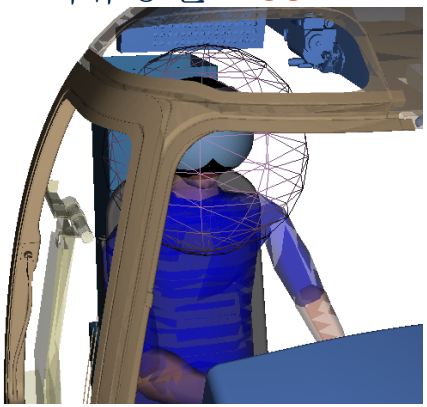


50th 대표인체모델
여유공간: 253 mm





95th 대표인체모델
여유공간: 258 mm



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Accessibility Evaluation Scale: KHP

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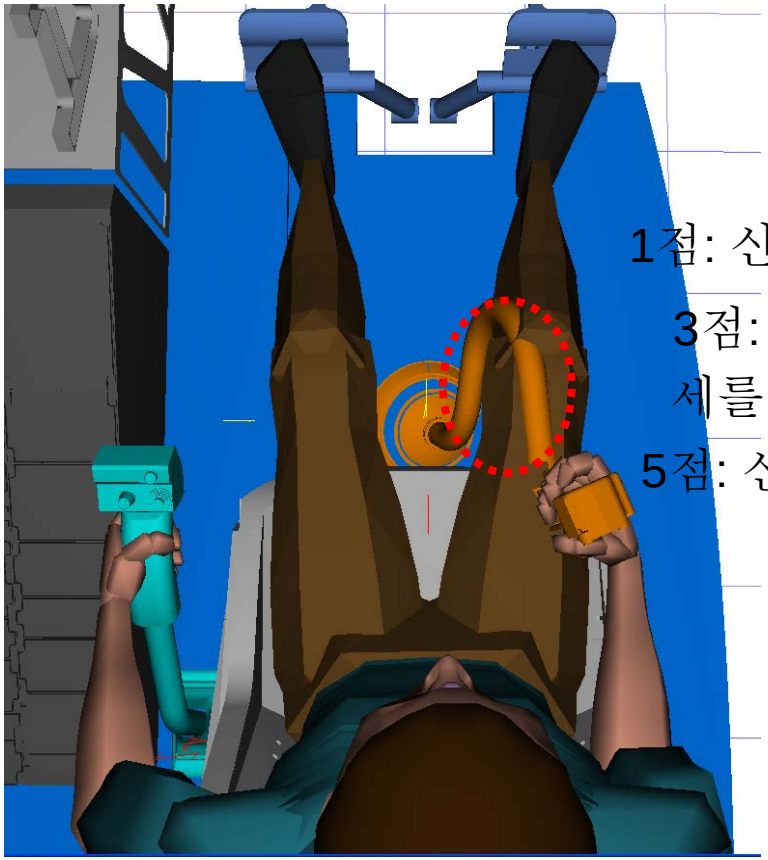
- 신체와 조종실 설계요소 간의 접촉 여부에 따라 5점 scale 3 등급(1점: 매우낮음, 3점: 보통, 5점: 매우높음) 평가 체계 개발



1점: 신체접촉 불가피

3점: 신체접촉이 있으나, 자세를 바꾸면 접촉 회피 가능

5점: 신체접촉 없음

Design Application: Visibility

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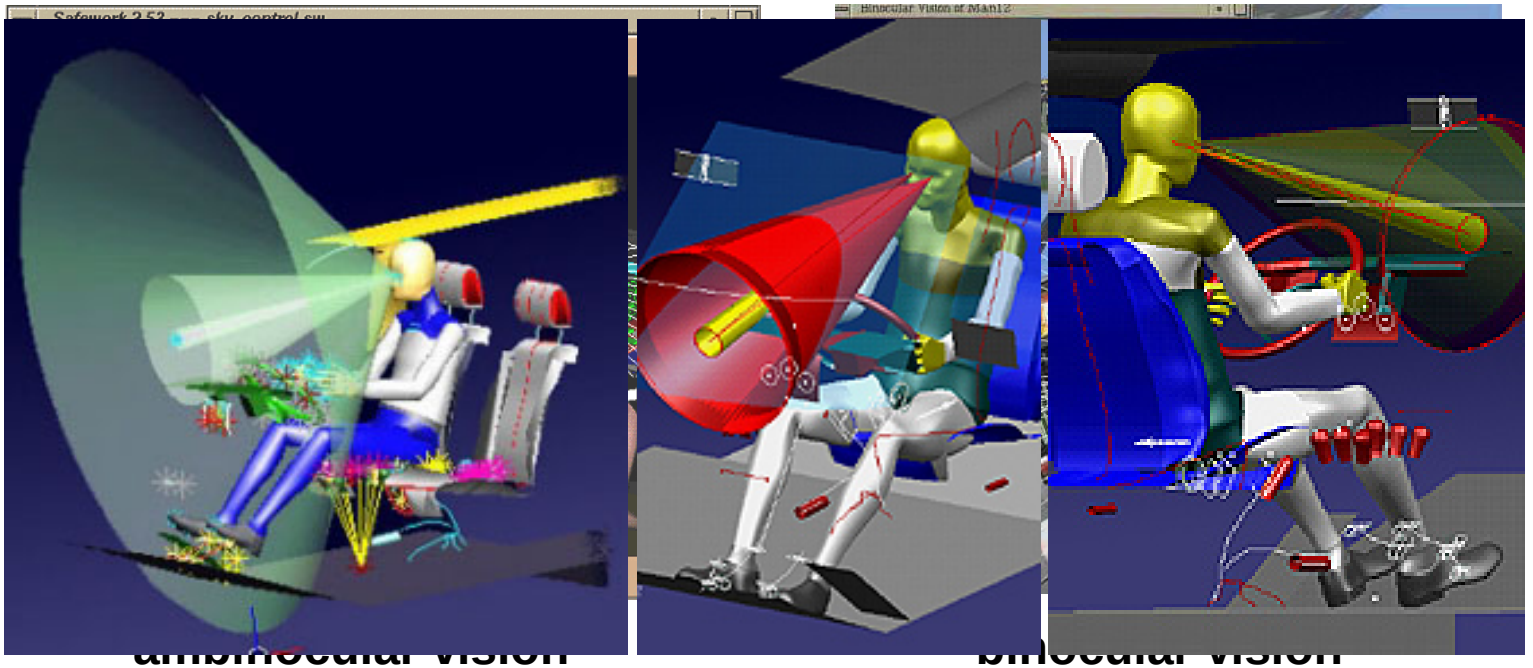
- **Evaluating the visual fields of the user by using view cones and view windows.**



Design Application: Visibility - KHP

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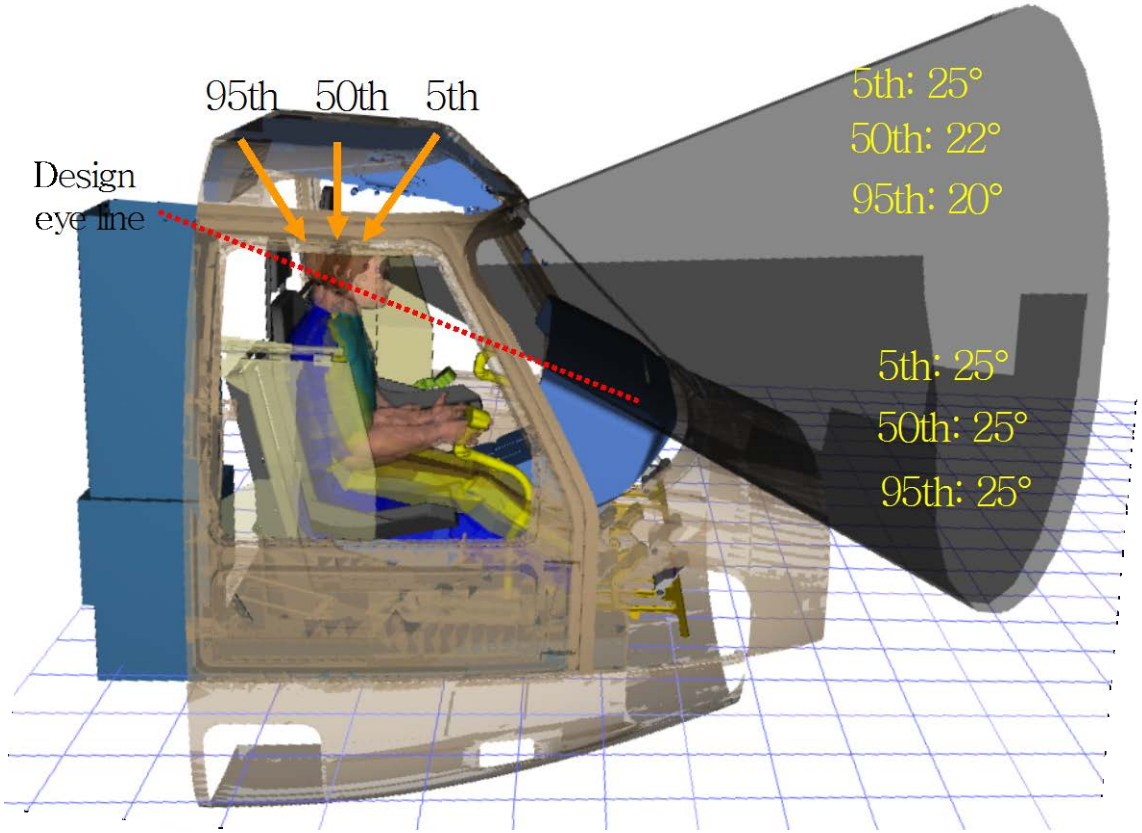
- 대표인체모델 3명에 대한 상방 및 하방 시야각 분석: MIL-STD 충족
  - 상방 시야각: 20 ~ 25° (MIL-STD: 20° at DEP)
  - 하방 시야각: 25° (MIL-STD: 25° at DEP)



Design Application: Visibility - KHP

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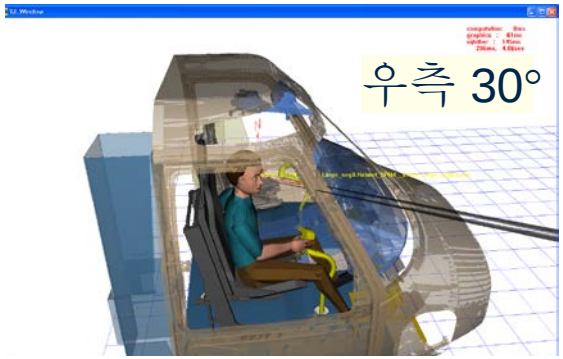
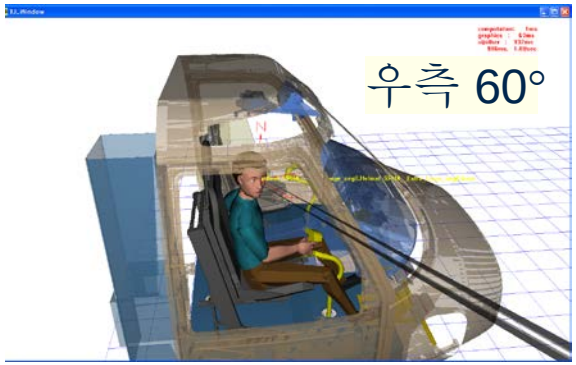
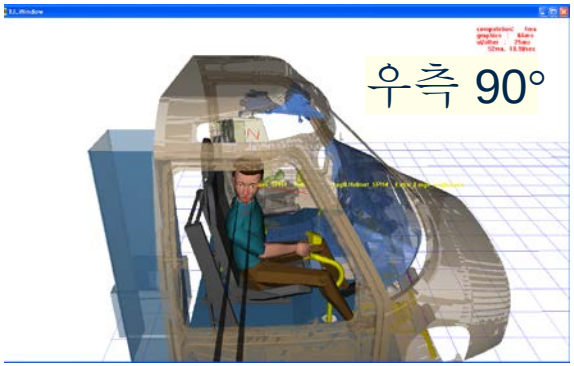
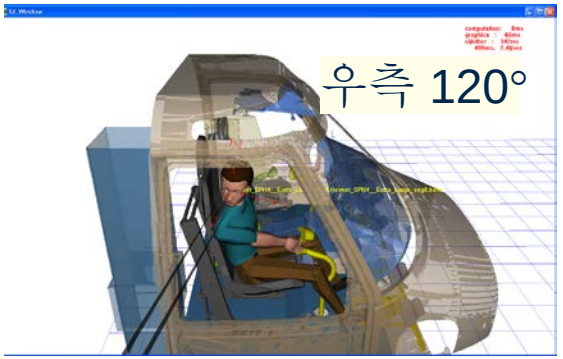
- 전방(0°) 및 우측 방향 경계(30°, 60°, 90°, 120°)에 대한 시계 적절성 평가
  - 대표인체모델 3명 모두 전방 및 우측 방향 120° 경계 시야 확보가 됨
  - 우측 방향 30° 경계 시 동체의 frame 시야 중심에 보임









Design Application: Visibility - KHP

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- 전방(0°) 및 우측 방향 경계(30°, 60°, 90°, 120°)에 대한 시계 적절성 평가
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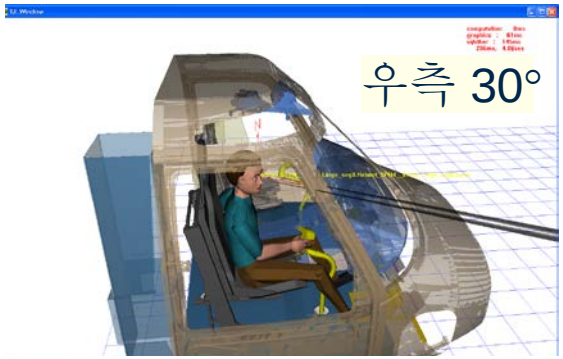

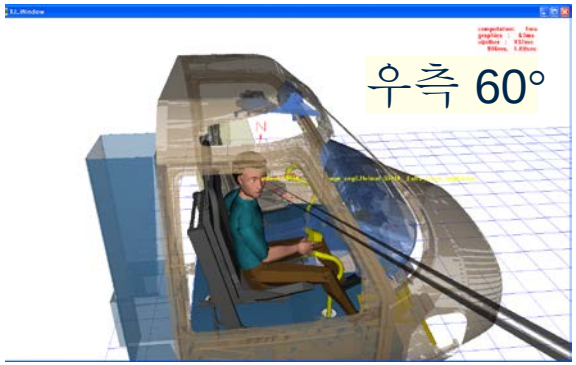

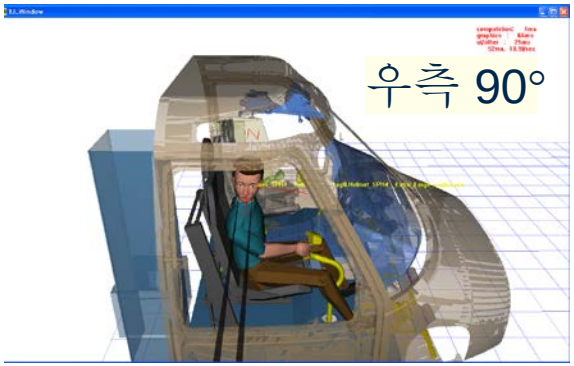

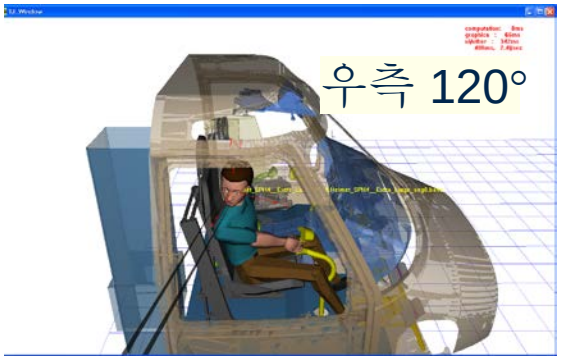

Design Application: Reach

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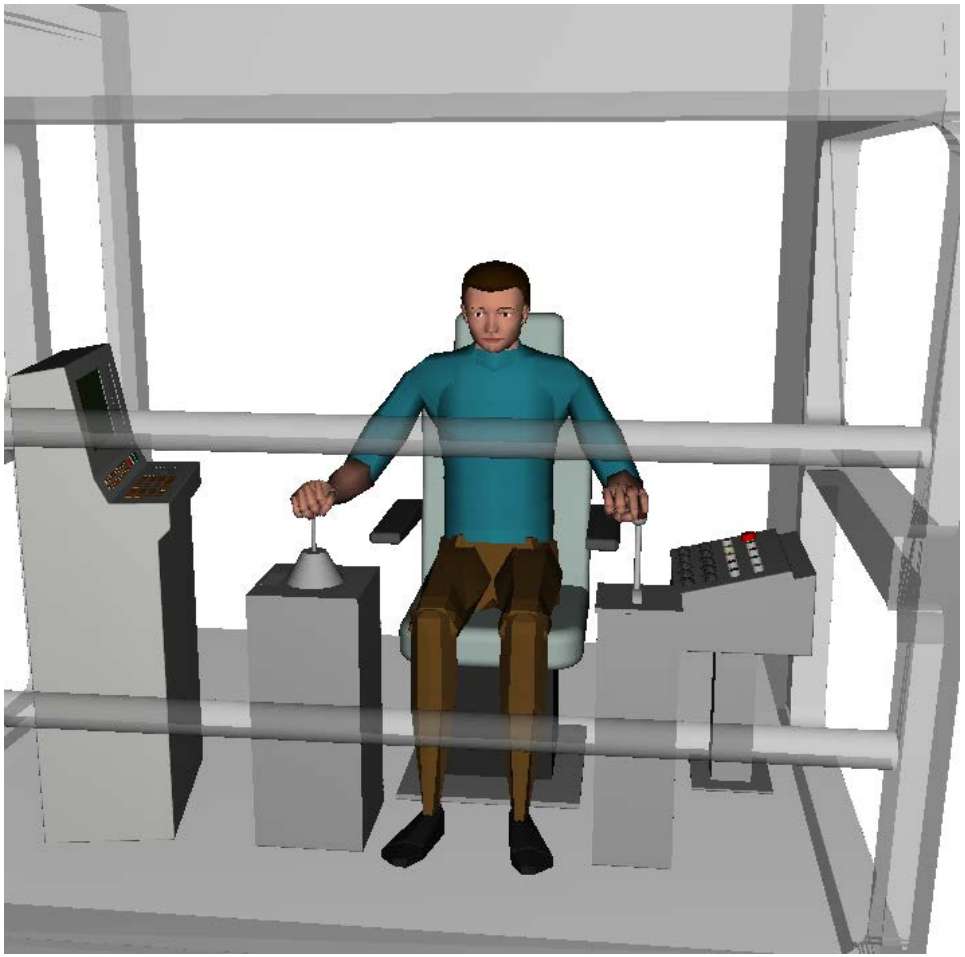
- **Predicting the reach volume or reachability of the user to operate controls, buttons, or switches in the system.**



Design Application: Reach

Ergonomic Design Technology Lab

- Predicting the reach volume or reachability of the user to operate controls, buttons, or switches in the system.

Generic reach envelope

Target-specific reach path

Design Application: Reach - KHP

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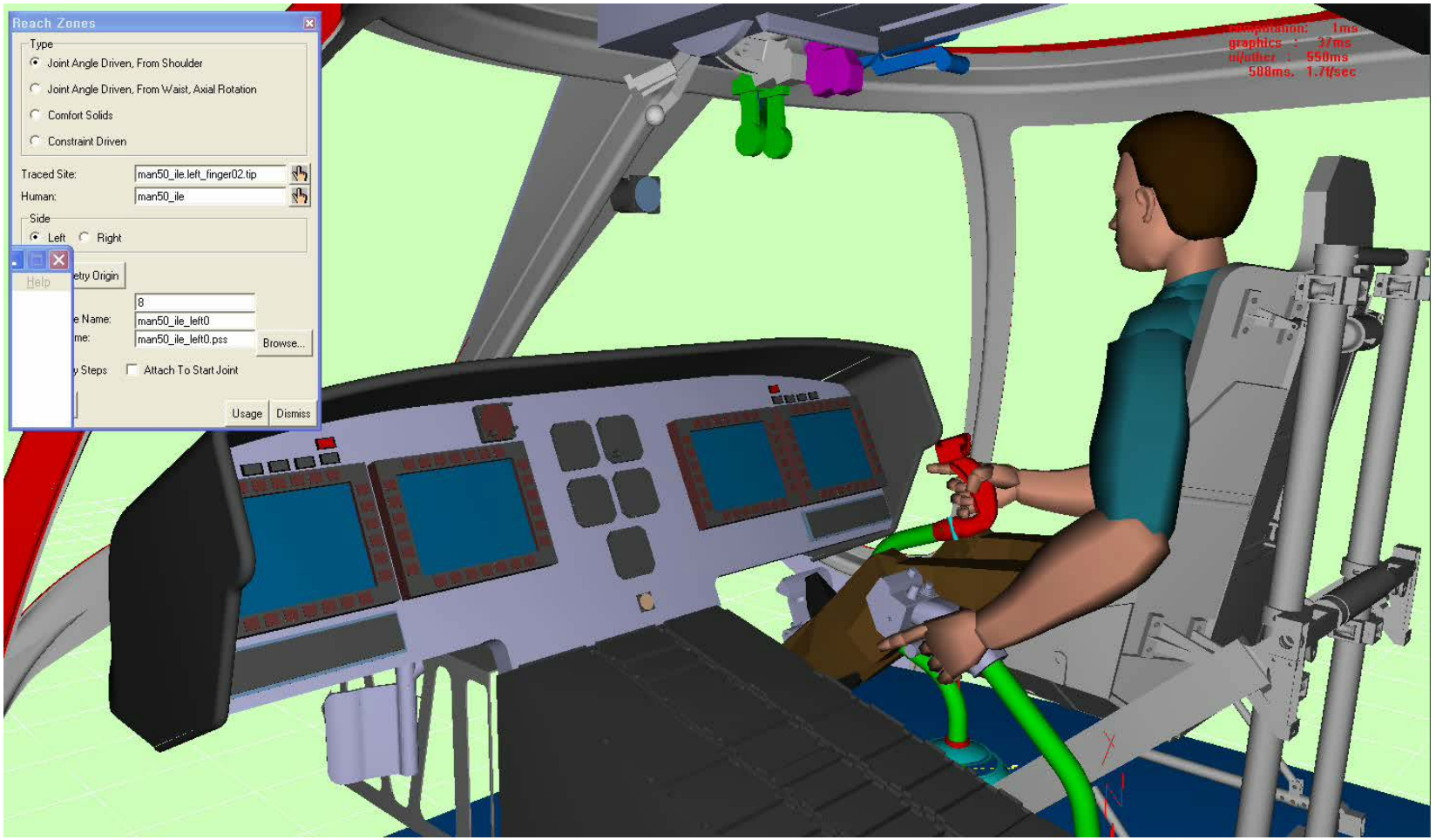

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Design Application: Posture

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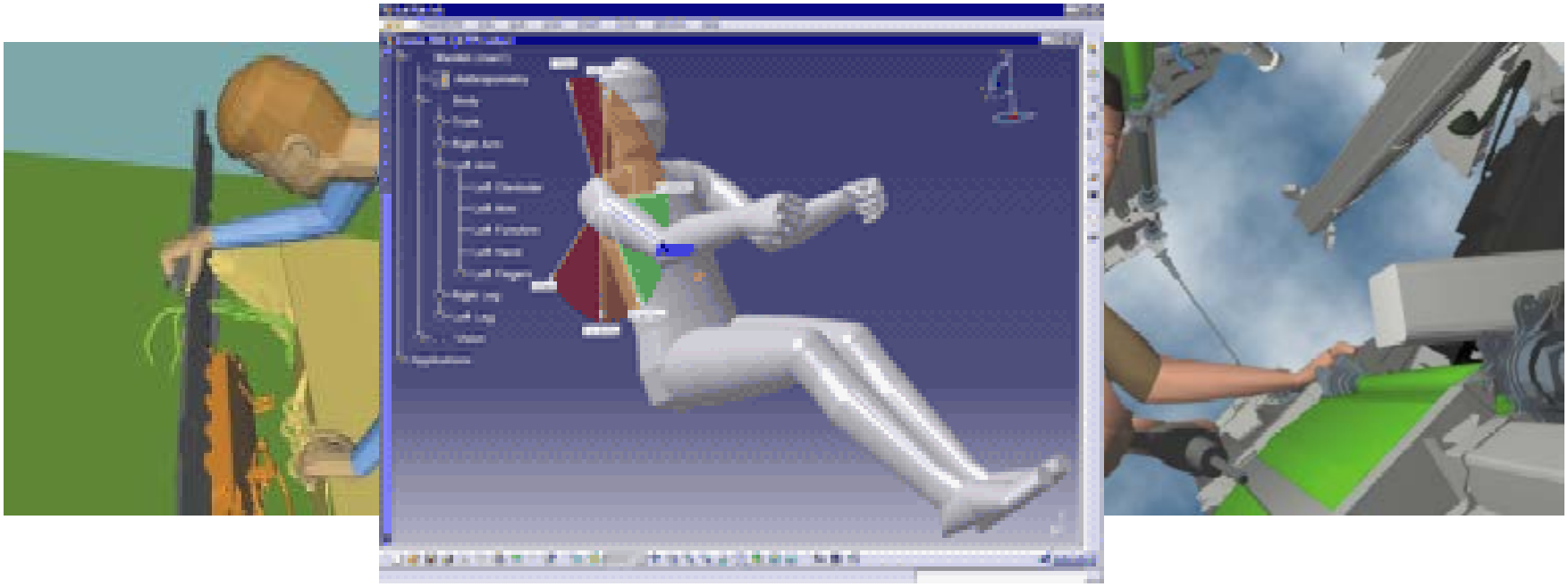
- **Predicting and evaluating the posture of the user when conducting a specific task.**



Posture color coding for evaluation

Design Application: Posture - KHP

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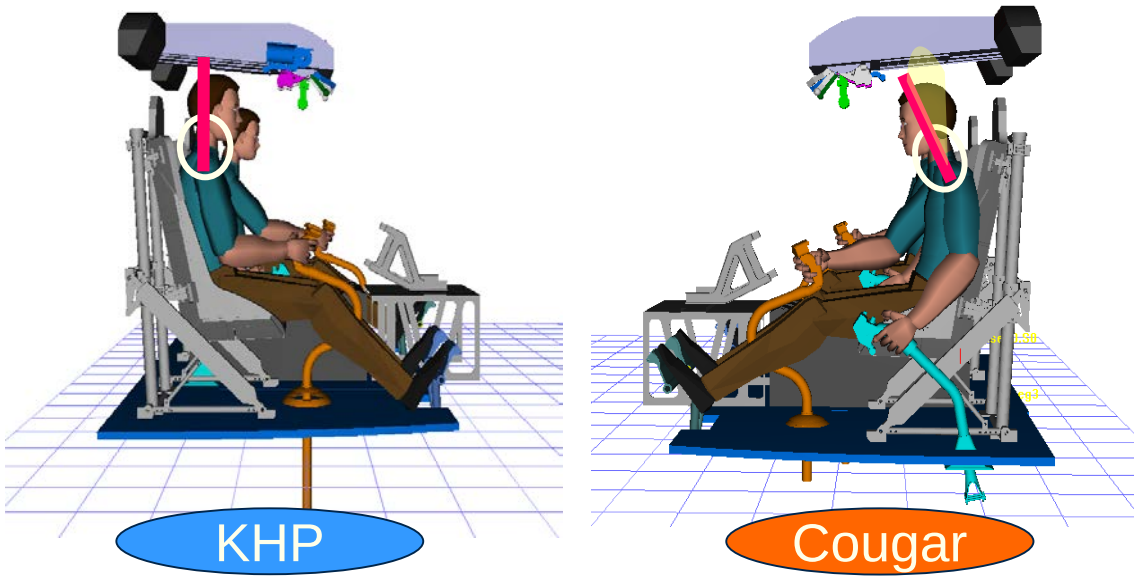
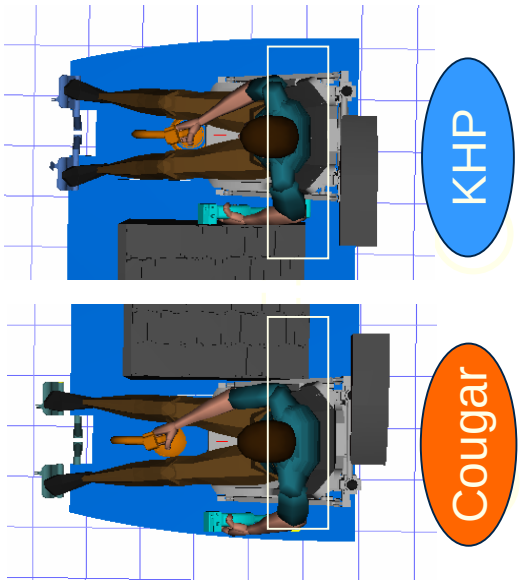
Cougar design은 KHP design 보다 목이 많이 굽혀짐(flexion)
- KHP: Neck flexion = 0.0°
- Cougar: Neck flexion = 15.2°

원인: Cougar는 DEP가 KHP에 비해 아래에 위치 (전: 1.2cm 하: 4.4cm)

Side view



Plan view



Posture Evaluation Scale - KHP

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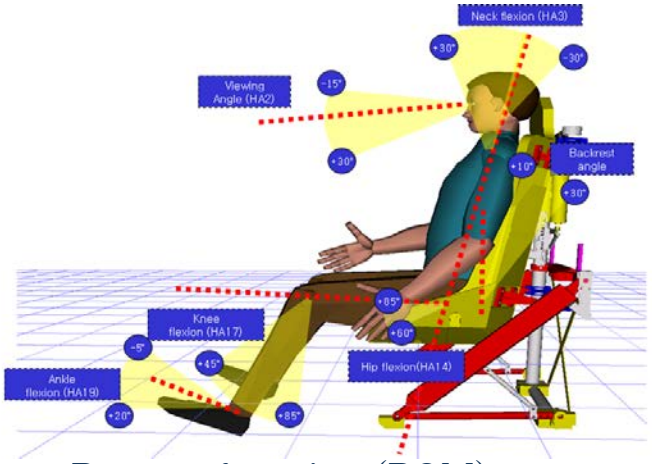
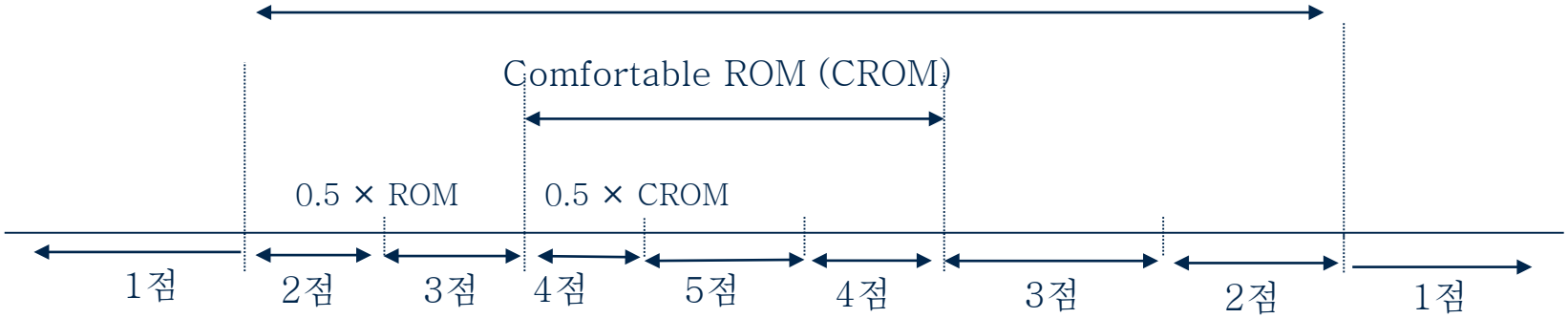
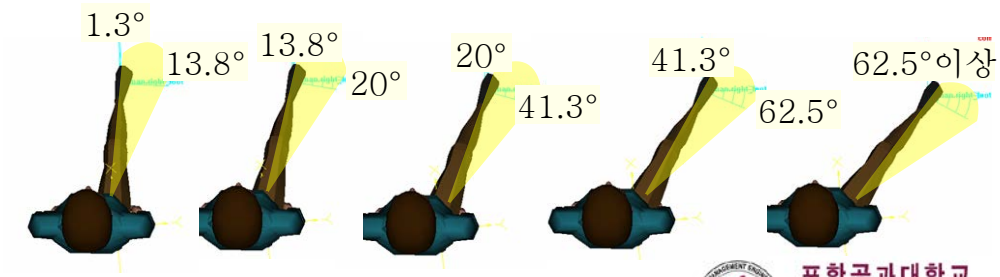


Range of motion (ROM)





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Design Application: Posture - KHP

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- **KHP design**은 **Cougar**에 비해 무릎과 어깨의 자세가 좋음

구분	KHP design	Cougar design
Neck flexion	5	4
Elbow flexion	5	4
Knee flexion	4	1
Shoulder flexion	5	3
평균	4.75	3

Design Application: Synthesis - KHP

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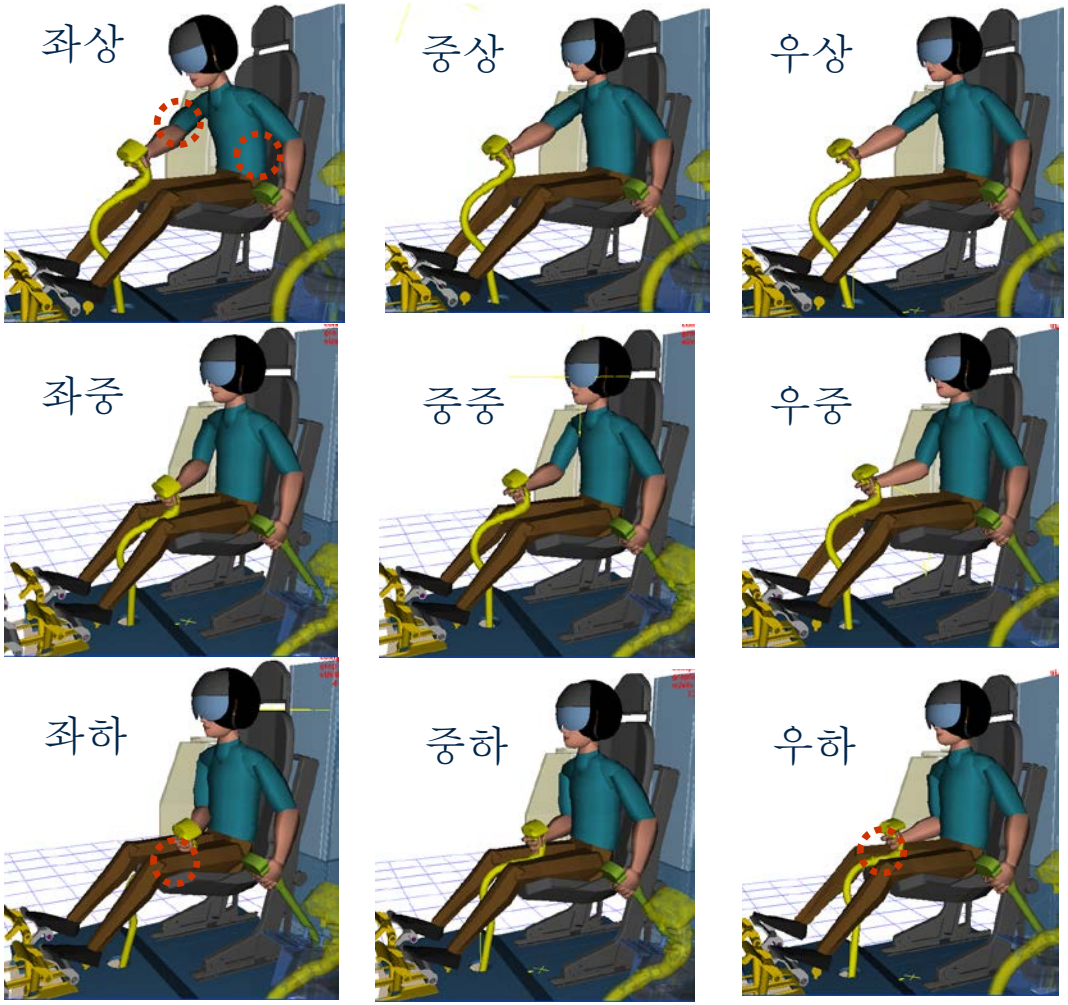
- 5th %ile 대표인체모델의 cyclic control 조작 (9개 위치)에 따른 자세 분석 사례



Design Application: Synthesis - KHP

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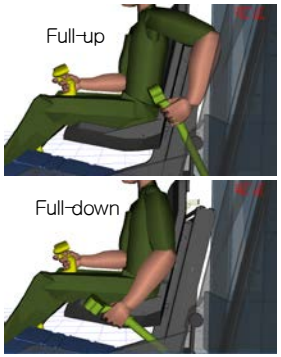
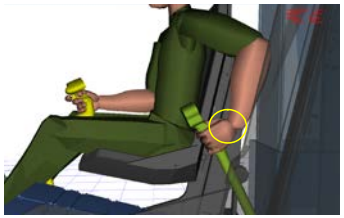
- Collective 조작 2개 위치에 대해 자세 편의성, 도달 용이성, 여유공간 적절성 평가

평가 위치		자세 편의성	
	Collective control를 full-up, full-down 조작		• 도달 점수: 4.1 ~ 4.5 점 • Full-up 조작 시 과도한 손목 편향 발생 (collective stick 손잡이 곡률의 인간공학적 설계 필요)
도달 용이성		**여유공간 적절성**	
	• 도달 점수: 4 ~ 5점 • 대표인체 3명 모두 팔(어깨와 팔꿈치)만 사용하여 collective control 조작 가능		Collective control을 full-up 조작 할 때 조종석 등받이와 위팔이 접촉되나, 팔을 약간 벌려주면 접촉을 피할 수 있음

Design Application: Biomechanical Analysis

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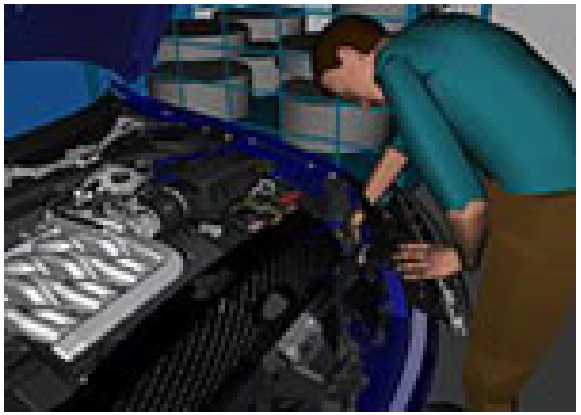
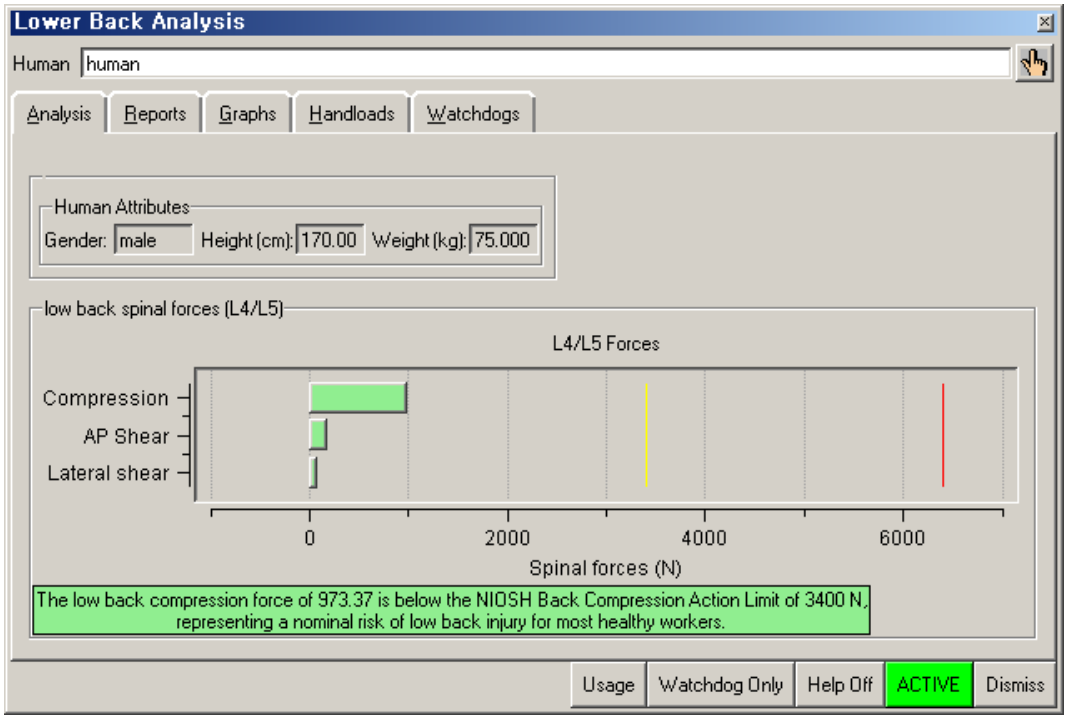
- **Predicting the biomechanical stress on the body segments for a designated work condition and comparing with NIOSH guidelines.**





Benchmarking: Biomechanical Analysis

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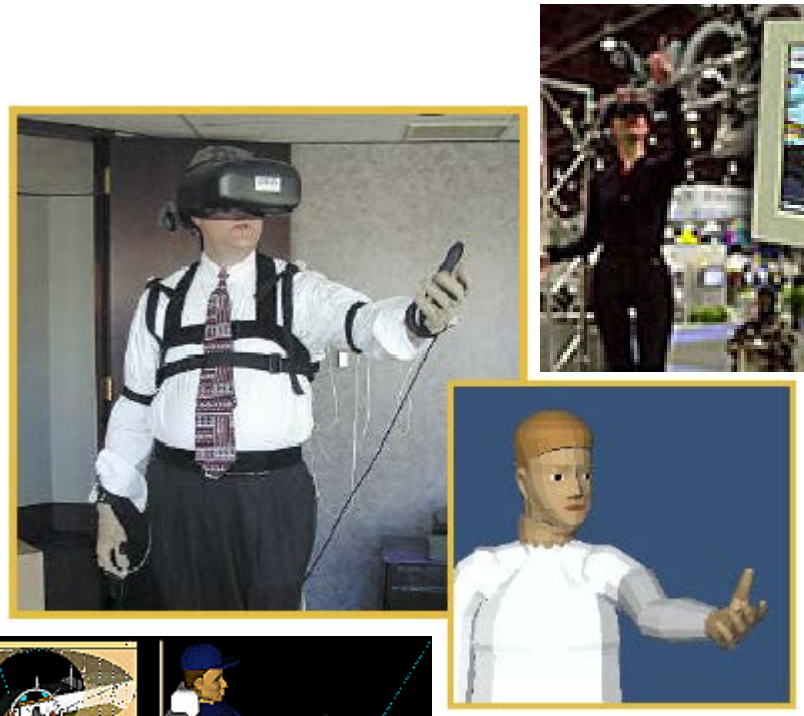
JACK	SAFEWORK	RAMSIS
• Low back spinal force analysis • Static strength prediction • NIOSH lifting analysis • Predetermined time analysis (MTM-1 system) • Rapid Upper Limb Assessment (RULA) • Garg's metabolic energy expenditure • Snook table (manual handling limits) • Fatigue/recovery time analysis • OWAS working posture analysis	• Balance calculation • NIOSH lifting analysis • RULA • Snook table (manual handling limits)	• Postural comfort analysis • Orthopedic assessment of the spine curvature • Force table with feasible and recommended values • Force analysis based on the Simens-Burandt method (gender, age, physical condition, hand, job-type)

Virtual Reality Interfaces



- Motion capturing devices
  - Flock of birds
  - CyberGlove
  - Vicon Motion system
  - Motion Analysis system
- Head mounted displays
- Haptic devices

Q & A

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2007년 10월 서울 Air Show에 전시된 KHP Mockup