Simulation Applications in Training

Valerie J. Gawron PhD
January 23, 2017

Agenda

- 11:00 to 12:00
  - Role of Simulation in a Training Curriculum
    - Curriculum Evaluation
    - Transfer of Training
- 1:00 to 2:00
  - Traditional Types of Simulators Used in Training
    - Static Mockups
    - Dynamic Mockups
    - Part Task Simulators
    - Full Mission Simulators
    - In-flight Simulators
  - Nontraditional Types of Simulators Used in Training
    - Above Real Time Training
    - Distributed Network of Dissimilar Simulations
    - Virtual Reality
    - Flatworld
    - Embedded Training
    - Cell Phones
    - iPod
    - Gaming
    - Weightlessness Simulators

Microsoft clip art

Role of Simulation in a Training Curriculum

- **Curriculum Evaluation**
  - **A specified fixed course of study**
  - **Lecture, exercises, simulators**
- **Transfer of Training**
  - **Definition - Application of a skill learned in a simulator to the real world**
  - **Examples**
    - **Flight simulators to aircraft**
    - **Surgical simulators to human patient surgery**
    - **Checkpoint simulators to baggage inspection**

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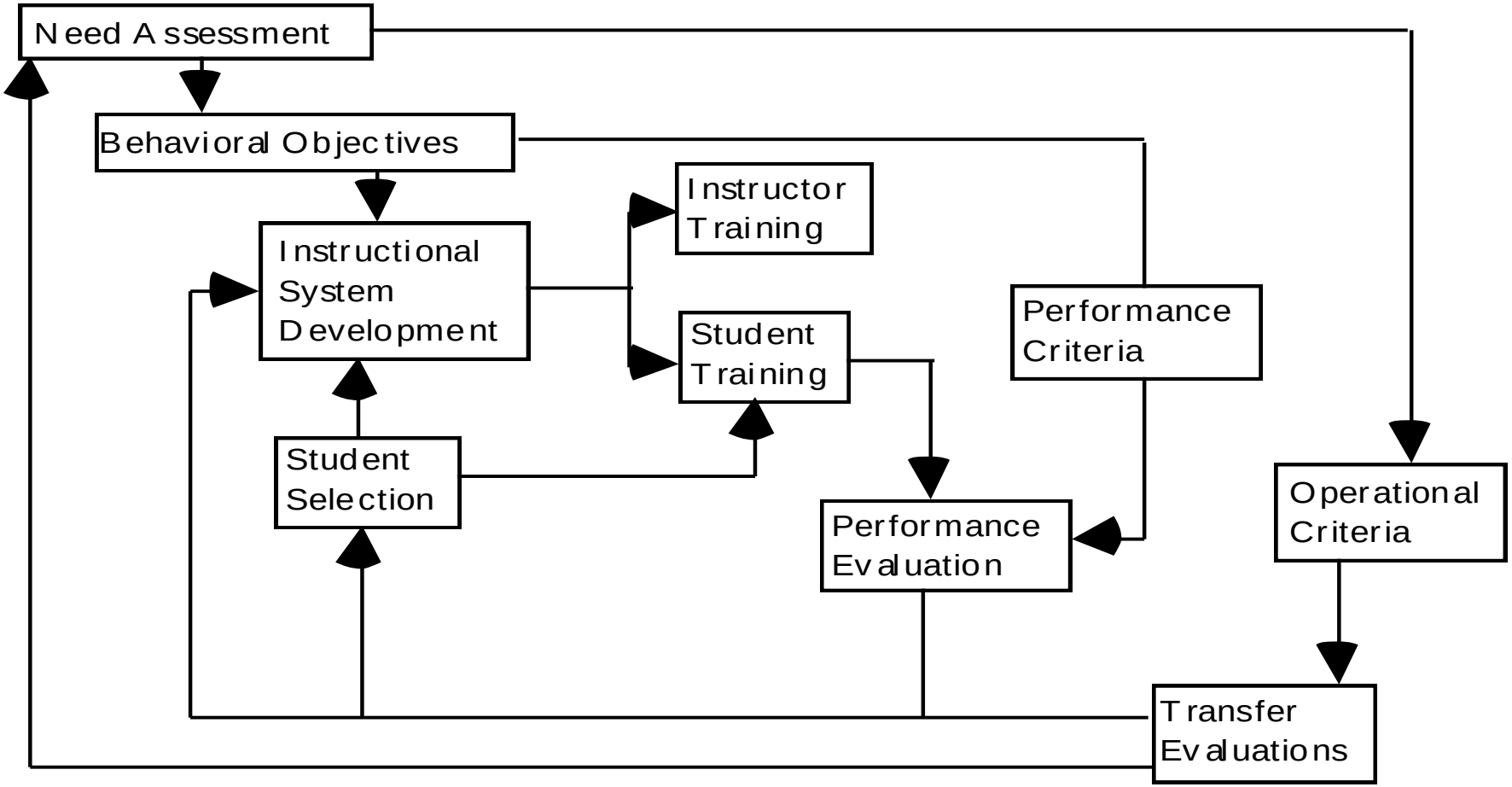
Curriculum



Roscoe, S.N., Jensen, R.S., and Gawron, V.J.: "Introduction to Training Systems." In S.N. Roscoe (Ed.) Aviation Psychology, Ames, Iowa: Iowa State University Press, 1980, p. 179

Curriculum Evaluation

- The Ten Cs
- Performance Evaluation
- Workload Analysis
- Situational Awareness Assessment

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The Ten Cs – 1: Completeness

- **Training must include all components of system that will be experienced by operator**
- **Components consist of control operation, display symbology and text, and all system procedures**

http://www.defense.gov/multimedia/

The Ten Cs – 2: Clarity

- **All terminology must be unambiguous. Terms should be easy to understand.**
- **AI**
  - **Attitude Indicator**
  - **Airborne Interceptor**
  - **Artificial Intelligence**

Courtesy US Air Force

The Ten Cs – 3: Conciseness

- **Training must be provided in as <u>few words</u> as possible**
- **Sentence structure should <u>not</u> include parenthetical material or appended phrases**

Courtesy US Air Force

The Ten Cs – 4: Consistency

- **Throughout training, <u>same terminology</u> should be unanimously used for same training component.**
- **Should be complete agreement with what has been previously stated in the training**

DefenseImagery.mil

Courtesy US Air Force

Scud
SS-1
TEL (transporter-erector-launcher)
TELAR (TEL and radar)

The Ten Cs – 5: Compactness

- **All training material on single component should be provided in a single, short training package**

Courtesy US Air Force

The Ten Cs – 6: Currency

- **Training material must reflect <u>current state of the system</u> including:**
  - **Appearance, placement, labeling, and operation of controls;**
  - **Wording and meaning of displayed information;**
  - **Order and actions in procedures; and**
  - **Application of techniques**

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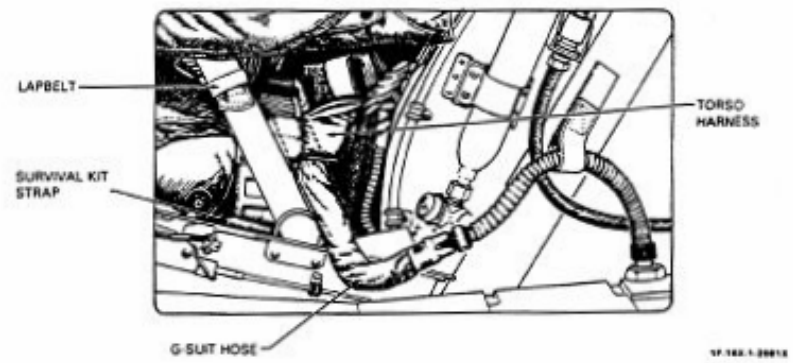
The Ten Cs – 7: Construction

- **Training should build on previous material and proceed from simple to complex**
- **Presentation should be highly formatted:**
  - **Place figure of control next to description of operation of control;**
  - **Place figure of display next to discussion of meaning of display; and**
  - **Provide procedures in numbered checklists**



NOTE

- The recommended routing of the g-suit hose (Figure 3) is directly under the torso harness and aft of the survival kit strap to reduce the possibility of a g-suit hose disconnect. G-suit hose routing must provide sufficient slack to allow for maximum mobility since in-flight reconnect is extremely difficult.

Courtesy US Air Force

The Ten Cs – 8: Communication

- **Words used in training should match:**
  - **Communication skill level, both written and spoken, of trainees and**
  - **Trainees' areas of expertise.**

- **Military pilots know Head Up Display (HUD) but not polyvinyl butyral (PVB) interlaying glass**

Courtesy US Air Force

The Ten Cs – 9: Competence

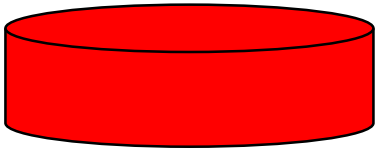
- **After training, trainee should possess the required skills and knowledge to perform the tasks trained**

Courtesy US Air Force

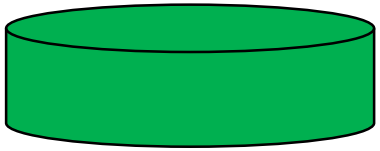
The Ten Cs – 10: Correctness

- **All material in the curriculum should be correct**

Turn Lights On



Blow Up Entire Building



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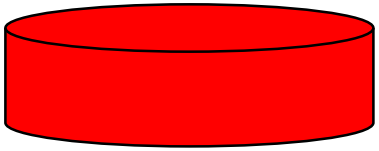

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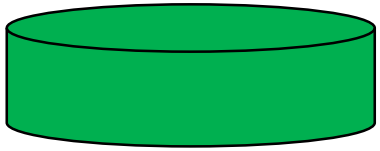


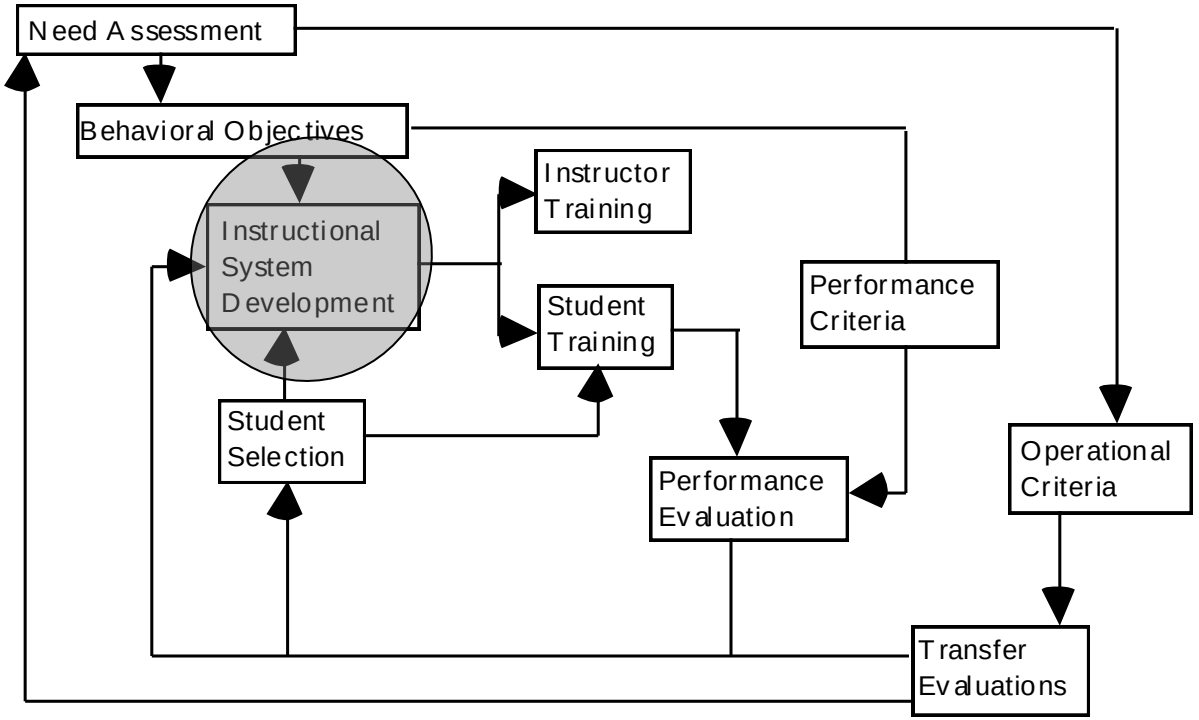
Does This Meet The Criteria?

Courtesy US Air Force Research Laboratory

Courtesy US Air Force

Instructional System Development

- **Use simulation to design live training exercises**

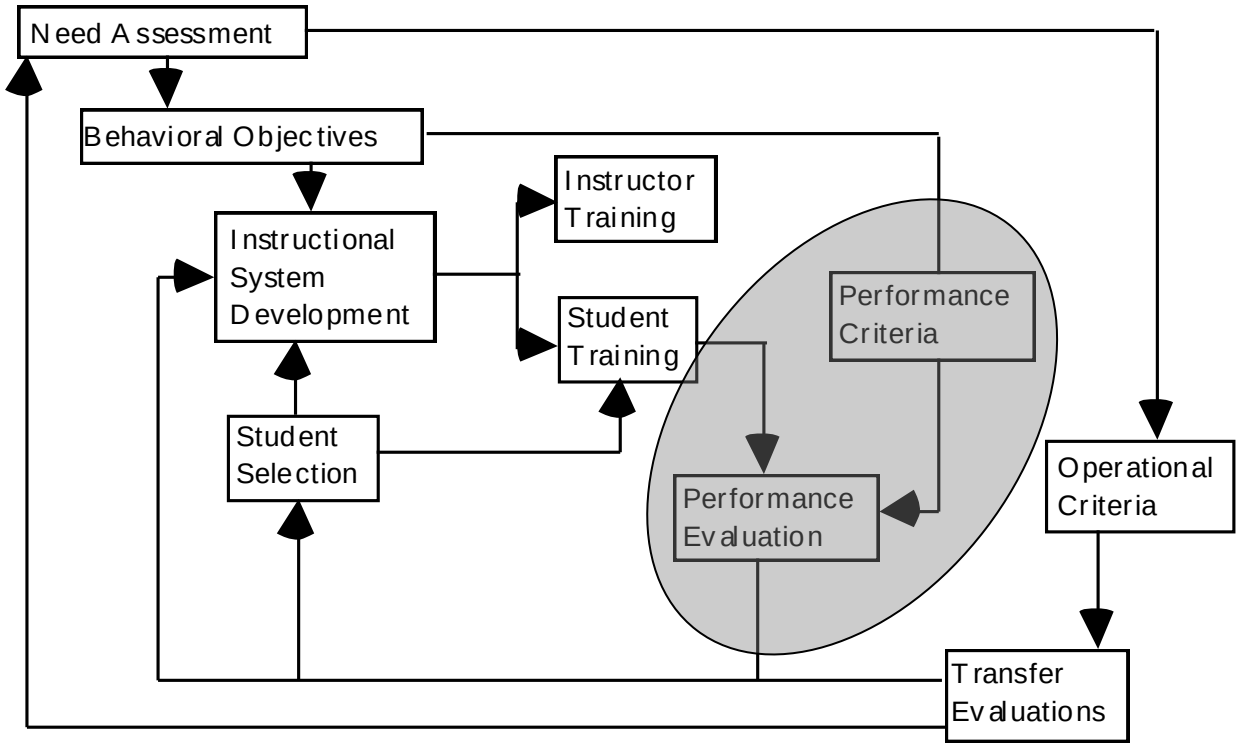


Use Simulation to Design Live Training Example

Courtesy US Army

Performance Evaluation

- **Determine how well the student meets the performance criteria**



Examples of Performance Criteria

ILS Segment		Parameter	Target	4	3	2	1	0
I	Arc Tracking	Altitude	3,000 feet	±50	±100	±150	±200	>200
		Airspeed	170 KIAS	±5	±10	±12.5	±15	>15
		DME	14 nm	±0.25	±0.50	±1.0	±1.5	>1.5
II	Localizer Intercept	Localizer	Centered/0 deg	±0.25	±0.50	±.75	±1.0	>1.5
		Roll Steering	Centered	±0.25	±0.50	±.75	±1.0	>1.0
		Airspeed	160 VIAS	+5.0, -2.5	+10.0, -5.0	+12.5, -5.0	+15.0, -5.0	>+15.0, -5.0
		Altitude	2,500 feet	±50	±100	±150	±200	>200
III	Localizer Tracking	Localizer	Centered/0 deg	±0.25	±0.50	±1.0	±1.5	>1.5
		Roll Steering	Centered/0 dots	±0.25	±0.50	±0.75	±1.0	>1.0
		Altitude	2,500 feet	±50	±100	±150	±200	>200
IV	ILS Tracking	Localizer	Centered	±0.25	±0.50	±1.0	±1.5	>1.5
		Roll Steering	(0 dots)	±0.25	±0.50	±0.75	±1.0	>1.0
		Glideslope	Centered/0 dots	±0.25	±0. 50	±1.0	±1.5	>1.5
		Pitch Steering	0 deg	+0.5, -1.0	+1.0, - 2.0	_1.0, - 2.5	+1.0, -3.0	>+1.0 , - 3.0
V	Decision Height	Localizer	Centered/0 dots	±0.25	±0.50	±1.0	±1.5	>1.5
		Roll Steering	Centered/0 dots	±0.25	±0.50	±.1.0	±1.5	>1.5
		Glideslope	Centered/0 dots	+0.25, -0	+0.5, -0.25	+1.0, -0.5	+1.5, -1.0	>+1.5, -1.0
		Pitch Steering	Centered/0 dots	±0.25	±0.50	±1.0	±1.5	>1.5
		Airspeed	140 KIAS	+5.0, -2.5	+10.0, -5.0	+12.5, -5.0	+15.0, -5.0	>+15.0, -5.0
		Altitude	332 feet	+25, -0	+50, -5	+100, -25	+150, -50	>+150, -50

Bailey, R.E.; Knotts, L.H.; Priest, J.E.; Gawron, V.J.; Parada, L.O.: "Evaluation of Proposed USAF HUD Standard, Session II," Calspan Report No. 7738-14, February 1993.

Example of After Action Review

Courtesy Sarnoff Corporation

Workload Analysis

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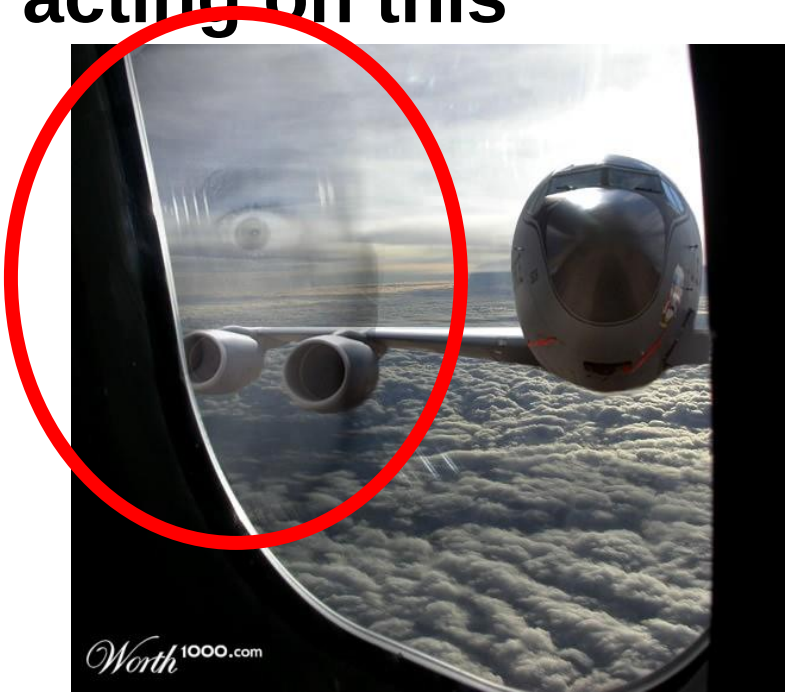
- **Definition - effort expended by human operator in accomplishing imposed performance criteria**
- **Measures**
  - **Performance**
    - **Stand-alone measures - as workload increases, additional processing degrades performance**
    - **Secondary task measures - operator performs primary task within criteria and uses spare capacity to perform secondary task; decrement in secondary task is workload**
  - **Subjective estimates**

Workload Analysis for Drivers

Situational Awareness Assessment

- **Definition - detecting information, processing information with relevant knowledge to create mental picture of current situation, and acting on this picture**
- **Measures**
  - **Subjective estimates**
  - **Observation**
  - **Physiological**

Garner, K.T. Situational Awareness: what is it? Can it be improved? Arlington, VA: Naval Air Systems Command, 1996.



Kate Askew | Graphic Designer
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Subjective Measure Example
SA Global Assessment Technique (SAGAT)

- Simulation stopped at random times
- Comparison of perceived and real
- Graphic computer program for queries

Courtesy The MITRE Corporation

Observation Measure Example
Crew SA

- Expert observers rate crew coordination
- Develop information transfer matrices
- Classify decision or nondecision information
- Requires open/frequent communication among crew members
- Requires team of expert observers

Physiological Measure Example
EOG

Courtesy US Air Force

Training That Failed

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Role of Simulation in a Training Curriculum

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Transfer of Training

- $\frac{Y_0 - Y_x}{Y_0} \times 100$
- **where:**
  - Y_0 = time, trials, or errors required by a group of students to reach the performance criterion <u>without training</u> in the simulator
  - Y_x = time, trials, or errors required by a group of students to reach the performance criterion <u>with x hours</u> in the simulator

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Diminishing Returns of Training

- **First hour in a simulator can save more than one hour in the aircraft**
- **Twentieth hour may not**
- **Simulators are associated with decreasing increments of actual flight hours saved**
- **Incremental savings for each hour in a simulator are calculated as the Incremental Transfer Effectiveness Ratio**

Microsoft clip art

Incremental Transfer Effectiveness Ratio (ITER)

- **ITER = $\frac{Y_{X - \Delta X} - Y_X}{\Delta X}$**
- **where:**
  - **$Y_{x - \Delta X}$ = time, trials, or errors required by a group of students to reach the performance criterion with X - ΔX hours in the simulator**
  - **Y_x = time, trials, or errors required by a group of students to reach the performance criterion with X training units in the simulator**
  - **ΔX = incremental unit of time, trials, or errors during training in the simulator**

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Cumulative Training Effectiveness Ratio (CTER)

- **CTER = $\frac{Y_O - Y_X}{X}$**
- **where:**
  - **Y_0 = time, trials, or errors required by a group of students to reach the performance criterion without training in the simulator**
  - **Y_x = time, trials, or errors required by a group of students to reach the performance criterion with X hours in the simulator**
  - **X = time, trials, or errors during training in the simulator**

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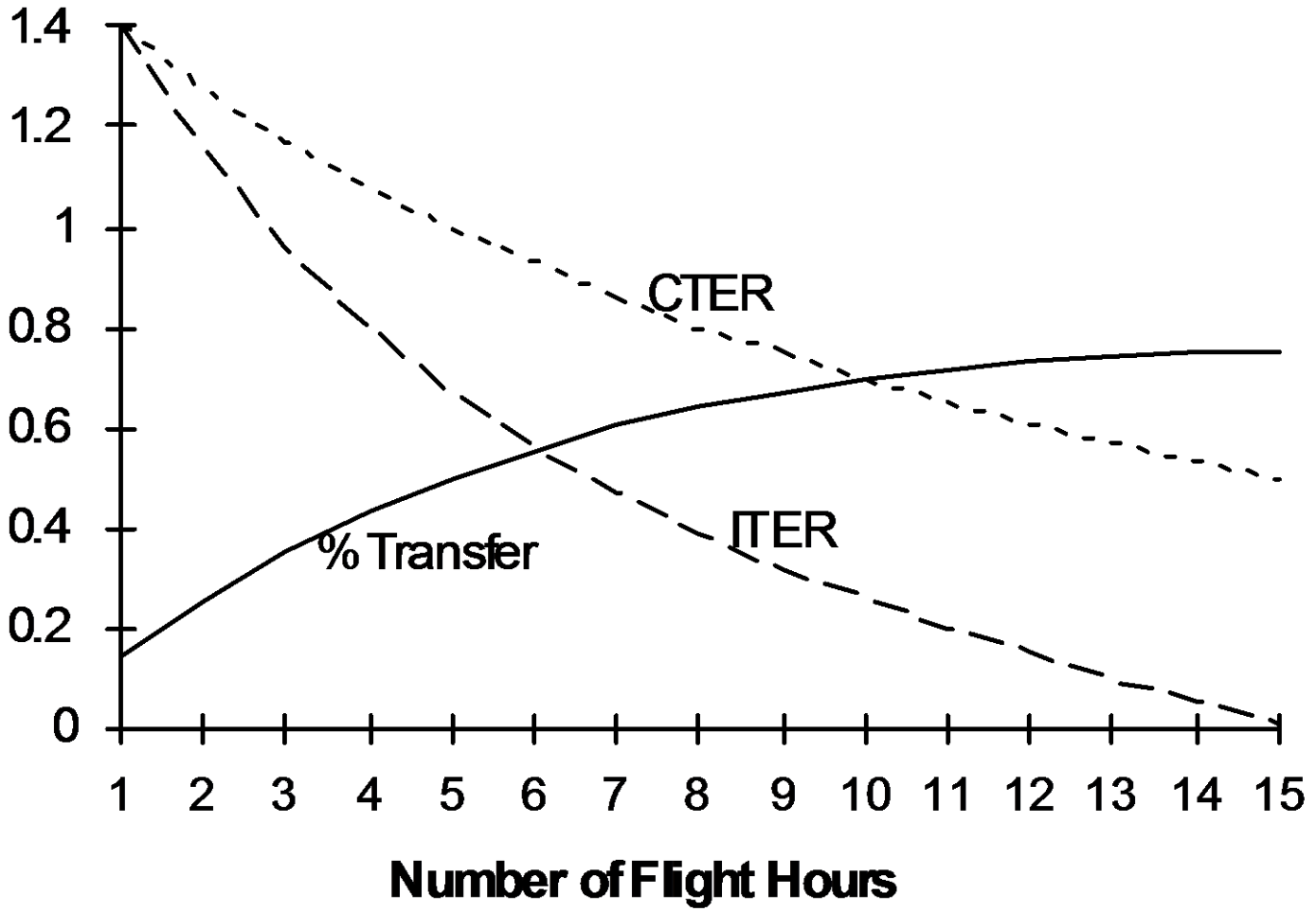
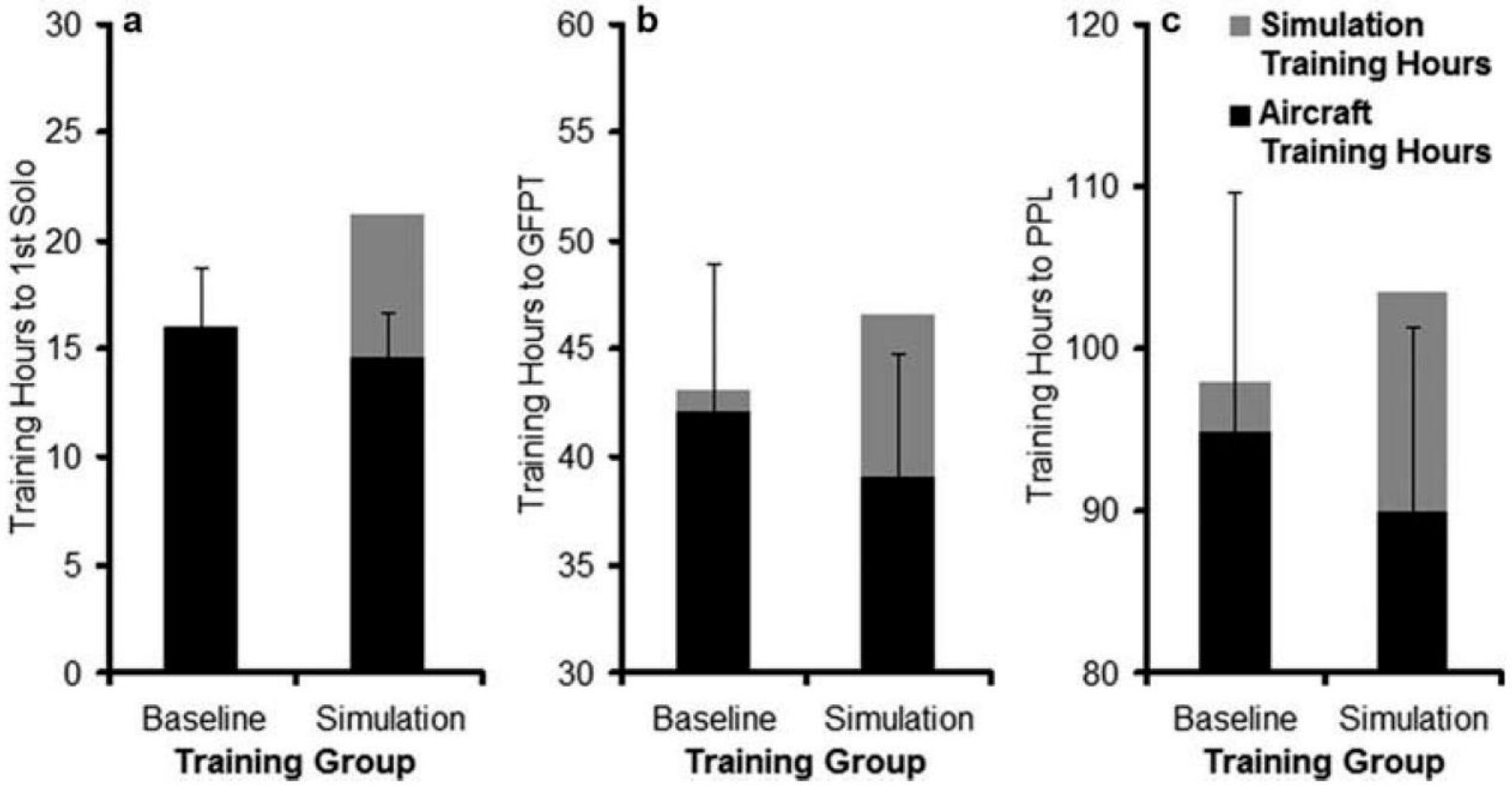
Training Effectiveness Ratios



Roscoe, S. N., Transfer and Cost Effectiveness of Ground-based Flight Trainers, in S. N. Roscoe (ed.) *Aviation Psychology*, Iowa State University Press, Ames, 1980.

Simulation May Require More Training Hours



McLean, G.M., Lambeth, S., and Mavin, T. The use of simulation in ab initio pilot training. International Journal of Aviation Psychology, 2016, 26(1-2), 36 – 45.

Simulation May Require Cost More

	Simulation Group		Baseline Group	
	Hours (Average)	Cost	Hours (Average)	Cost
Simulation hours: $200 per hour	13.5	$2,700.00	3	$600.00
Aircraft hours without QFI: $252 per hour	26.9	$6,778.80	28.3	$7,131.60
Aircraft hours with QFI: $357 per hour	63.2	$22,562.40	66.2	$23,633.40
Total cost		$32,041.20		$31,365.00

Note. QFI = qualified flying instructor.

McLean, G.M., Lambeth, S., and Mavin, T. The use of simulation in ab initio pilot training. International Journal of Aviation Psychology, 2016, 26(1-2), 36 – 45.

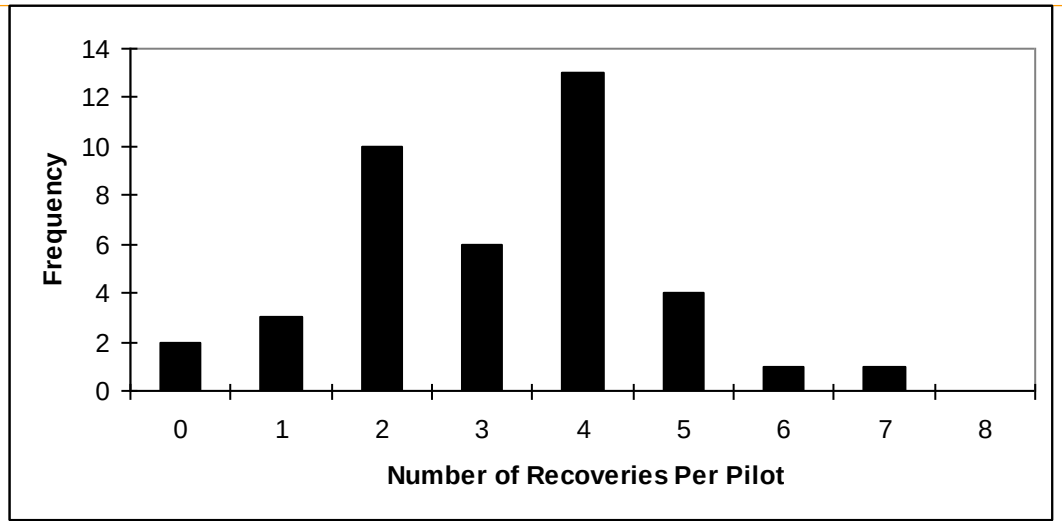
Transfer of Training Example

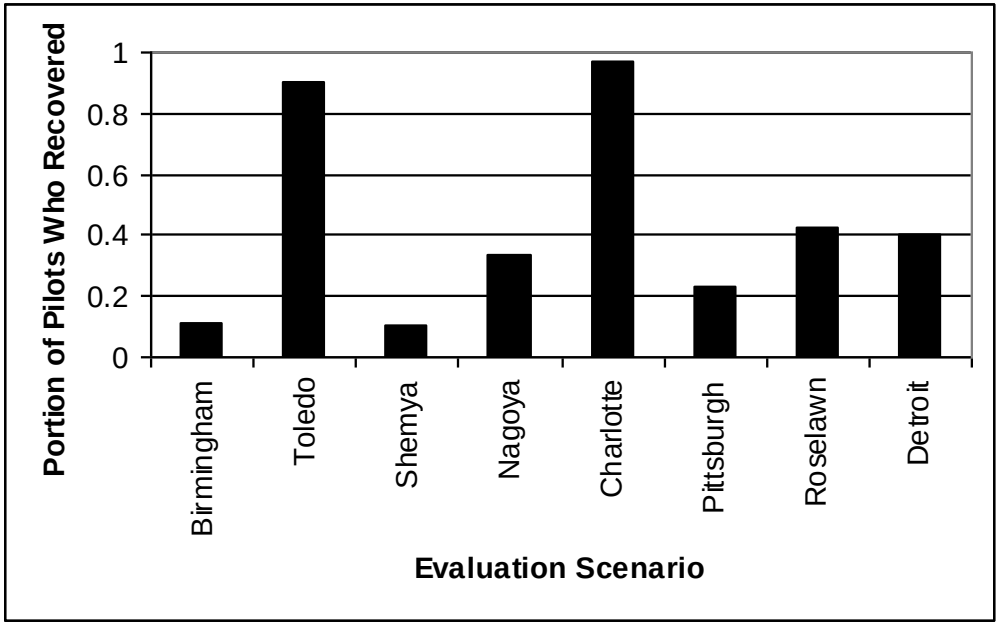
- **For commercial airlines, loss of control in an upset causes most fatalities**
- **Evaluation of airplane upset training:**
  - **No aerobatics training and no upset training**
  - **Aerobatics training and no upset training**
  - **No aerobatics training and no upset training**
  - **Aerobatics training and upset training**
  - **In-flight and no aerobatics training and no upset training**

Proportion of Pilots Who Recovered Aircraft

	Birmingham Microburst	Toledo Sink rate	Shemya Slats	Nagoya Autopilot	Charlotte Windshear	ittsburgh Rudder	Roselawn Icing	Detroit Icing
No Aero/No Upset	0.125	1.000	0.125	0.375	1.000	0	0.333	0.375
Aero/No Upset	0	0.750	0.125	0.250	1.000	0.125	0.500	0.500
No Aero/Upset	0.166	1.000	0	0.500	1.000	0.166	0.143	0.250
Aero/Upset	000	1.000	0.143	0.143	1.000	0	0.286	0.625
In-flight	0.286	0.750	0.143	0.429	0.857	0.857	0.857	0.250
Scenario average	0.115	0.900	0.107	0.339	0.971	0.230	0.424	0.400

Results





Gawron, V.J.: "Airplane upset training evaluation report" (NASA/CR-2002-211405). Moffett Field, CA: National Aeronautics and Space Administration, May 2002

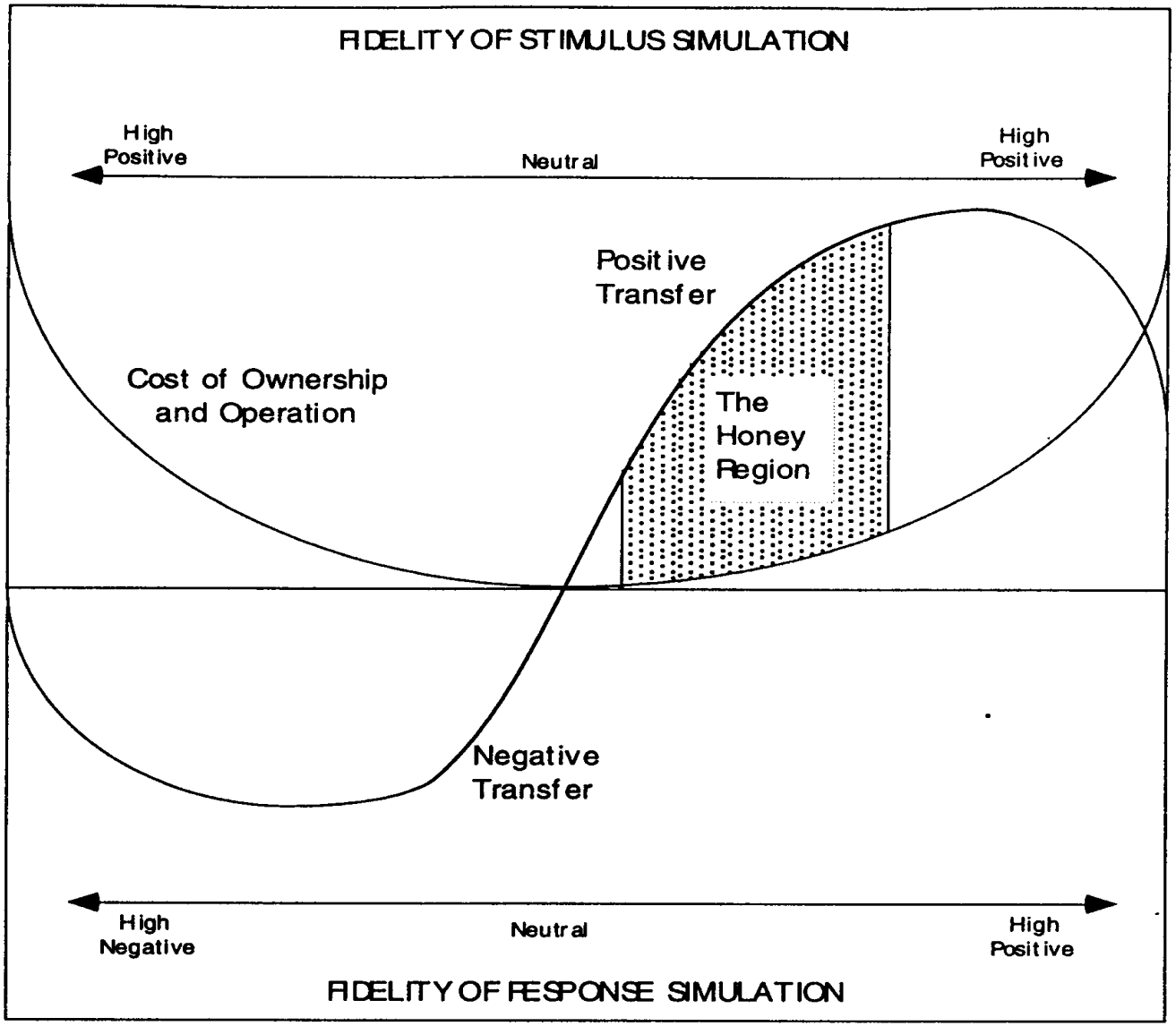
Transfer of Airplane Upset Training

Courtesy NTSB

Transfer of Airplane Upset Training

Courtesy NASA

Transfer as a Function of Fidelity



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Simulator Features – Motion Cues

Number	Feature	Definition	Fidelity
1.1	Vibration	Vibration testing on a "shaker" platform	Stimulus
1.2	Acceleration	Centrifuge testing for effects of sustained or transitory accelerations	Stimulus
1.3	Motion		
1.3.1	Low-fidelity	See Excursion Limits for Fidelity of Motion Cues	Stimulus
1.3.2	Moderate-fidelity	See Excursion Limits for Fidelity of Motion Cues	Stimulus
1.3.3	High-fidelity	See Excursion Limits for Fidelity of Motion Cues	Stimulus
1.3.4	Actual flight, no simulation	An actual flight environment in an aircraft other than the actual crewstation platform	Stimulus
1.4	Turbulence		
1.4.1	None	No turbulence or turbulence effects	Stimulus
1.4.2	Simulated	Effects of turbulence are simulated, including: 1) gust and buffet effects on aircraft handling characteristics, 2) vibration of displays and controllers, and 3) vibration of seat and/or restraint system	Stimulus
1.4.3	Real-world	Actual turbulence is present and affects aircraft handling characteristics, clarity of displays, response of controllers, and movement of the seat and/or restraint system	Stimulus

Gawron, V.J., Bailey, R., and Lehman, E.: "Lessons Learned in Applying Simulators to Crewstation Evaluation," The International Journal of Aviation Psychology, Volume 5, Number 2, 277-290, 1995.

Excursion Limits for Fidelity of Motion Cues

	Fidelity		
Kinematics	**Low fidelity**	**Medium fidelity**	**High fidelity**
Longitudinal Acceleration	$0.0 < \Delta g_x < \pm 0.5g$	$\pm 0.5 < \Delta g_x < \pm 1.5g$	$\pm 1.5 < \Delta g_x$
Longitudinal Velocity	$0.0 < \Delta v_x < \pm 2.5fps$	$\pm 2.5 < \Delta v_x < \pm 7.5fps$	$\pm 7.5 < \Delta v_x$
Longitudinal Displacement	$0.0 < \Delta x < \pm 2.5ft$	$\pm 2.5 < \Delta x < \pm 7.5ft$	$\pm 7.5 < \Delta x$
Lateral Acceleration	$0.0 < \Delta g_y < \pm 0.5g$	$\pm 0.5 < \Delta g_y < \pm 1.0g$	$\pm 1.0g < \Delta g_y$
Lateral Velocity	$0.0 < \Delta v_y < \pm 2.5fps$	$\pm 2.5 < \Delta v_y < \pm 5.0fps$	$\pm 5.0fps < \Delta v_y$
Lateral Displacement	$0.0 < \Delta y < \pm 2.5ft$	$\pm 2.5 < \Delta y < \pm 5.0ft$	$\pm 5.0ft < \Delta y$
Vertical Acceleration	$0.0 < \Delta g_z < \pm 0.5g$	$\pm 0.5 < \Delta g_z < \pm 1.5g$	$\pm 1.5g < \Delta g_z$
Vertical Velocity	$0.0 < \Delta v_z < \pm 2.5fps$	$\pm 2.5 < \Delta v_z < \pm 7.5fps$	$\pm 7.5fps < \Delta v_z$
Vertical Displacement	$0.0 < \Delta z < \pm 2.5ft$	$\pm 2.5 < \Delta z < \pm 5.5ft$	$\pm 7.5ft < \Delta z$
Pitch Acceleration	$0.0 < \Delta \dot{q} < \pm 0.5r/s^2$	$\pm 0.0 < \Delta \dot{q} < \pm 1.5r/s^2$	$\pm 1.5r/s^2 < \Delta \dot{q}$
Pitch Velocity	$0.0 < \Delta q < \pm 0.5r/s$	$\pm 0.5 < \Delta q < \pm 1.5r/s$	$\pm 1.5r/s < \Delta q$
Pitch Displacement	$0.0 < \Delta\theta < \pm 0.5rad$	$\pm 0.5 < \Delta\theta < \pm 1.5rad$	$\pm 1.5rad < \Delta\theta$
Roll Acceleration	$0.0 < \Delta \dot{p} < \pm 0.5r/s^2$	$\pm 0.5 < \Delta \dot{p} < \pm 1.5r/s^2$	$\pm 1.5r/s^2 < \Delta \dot{p}$
Roll Velocity	$0.0 < \Delta p < \pm 0.5r/s$	$\pm 0.5 < \Delta p < \pm 1.5r/s$	$\pm 1.5r/s < \Delta p$
Roll Displacement	$0.0 < \Delta\phi < \pm 0.5rad$	$\pm 0.5 < \Delta\phi < \pm 1.5rad$	$\pm 1.5rad < \Delta\phi$
Yaw Acceleration	$0.0 < \Delta \dot{r} < \pm 0.5r/s^2$	$\pm 0.5 < \Delta \dot{r} < \pm 1.5r/s^2$	$\pm 1.5r/s^2 < \Delta \dot{r}$
Yaw Velocity	$0.0 < \Delta r < \pm 0.5r/s$	$\pm 0.5 < \Delta r < \pm 1.5r/s$	$\pm 1.5r/s < \Delta r$
Yaw Displacement	$0.0 < \Delta\ddot{Y} < 0.5rad$	$\pm 0.5 < \Delta\ddot{Y} < 1.5rad$	$1.5rad < \Delta\ddot{Y}$

Gawron, V.J., Bailey, R., and Lehman, E.: "Lessons Learned in Applying Simulators to Crewstation Evaluation," The International Journal of Aviation Psychology, Volume 5, Number 2, 277-290, 1995.

Simulator Features – Visual Cues

Number	Feature	Definition	Fidelity
2.1	Field-of-view size		
2.1.1	Narrow field of view	<45º horizontal, <30º vertical	Stimulus
2.1.2	Wide field of view	>45º horizontal, >30º vertical	Stimulus
2.1.3	Full field of view	Actual crewstation field of view	Stimulus
2.2	Visual-scene fidelity		
2.2.1	Low detail	No texturing; <25K multi-faceted polygons per frame	Stimulus
2.2.2	Moderate detail	Shading, no texturing; >25K <100K multi-faceted polygons/frame	Stimulus
2.2.3	High detail	Texturing, shading; >100K multi-faceted polygons per frame	Stimulus
2.2.4	Real-world detail	Actual, real-world visual scene	Stimulus
2.2.5	Color	Full color spectrum	Stimulus
2.2.6	Monochrome	Monochromatic color	Stimulus
2.3	Target fidelity		
2.3.1	Low detail	<5 scan lines per target and <5 minutes of arc visual angle	Stimulus
2.3.2	Moderate detail	5 -10 scan lines per target & 5 to 10 minutes of arc visual angle	Stimulus
2.3.3	High detail	>10 scan lines per target and >10 minutes of visual angle	Stimulus
2.3.4	Real-world detail	Real-world sensor images, photographs, or videos	Stimulus
2.3.5	False-color target	Varies in color from real-world target by > 1 hue	Stimulus
2.3.6	Real-color target	Does not vary in color from real-world target by > 1 hue	Stimulus

Gawron, V.J., Bailey, R., and Lehman, E.: "Lessons Learned in Applying Simulators to Crewstation Evaluation," The International Journal of Aviation Psychology, Volume 5, Number 2, 277-290, 1995.

Simulator Features – Auditory Cues

Number	Feature	Definition	Fidelity
3.1	Engine noise		
3.1.1	Simulated engine noise	Actual engine noise from one aircraft or noise produced by a sound mixer	Stimulus
3.1.2	Actual engine noise	Actual engine noise or high-quality auditory recording of engine noise as functions of altitude, airspeed, and environmental conditions	Stimulus
3.2	Vibratory noise	Low-frequency noise associated with aircraft motion	Stimulus
3.3	Radio		
3.3.1	Simulated radio	Actual radio equipment is not used	Stimulus
3.3.2	Real radio	Actual radio equipment is used	Stimulus
3.4	Acoustic/airflow noise		
3.4.1	Simulated acoustic/airflow noise	Actual acoustic/airflow noise from one aircraft or noise produced by a sound mixer	Stimulus
3.4.2	Real acoustic/airflow noise	Actual acoustic/airflow noise or high-quality auditory recording of acoustic/airflow noise as functions of altitude, airspeed, and environmental conditions	Stimulus

Gawron, V.J., Bailey, R., and Lehman, E.: "Lessons Learned in Applying Simulators to Crewstation Evaluation," The International Journal of Aviation Psychology, Volume 5, Number 2, 277-290, 1995.

Simulator Features – Crewstation

Number	Feature	Definition	Fidelity
4.1	Displays		
4.1.1	Static non-operational mockups	Displays are simulated used non-functional mockups	Stimulus
4.1.2	Simulated operational displays	Displays are simulated using functional mockups	Stimulus
4.1.3	Actual displays	Actual, functional displays are present	Stimulus
4.2	Controls		
4.2.1	Static mockups	Controls are simulated using non-functional mockups	Response
4.2.2	Operational, representative controls	Controls are simulated using functional mockups	Response
4.2.3	Actual controls	Actual, functional controls are present	Response
4.3	Lighting		
4.3.1	Simulated lighting	Lighting matched in luminance but not spectrum	Stimulus
4.3.2	Actual lighting	Actual crewstation lighting present; out-of-crewstation lighting simulated	Stimulus
4.3.3	Operational conditions	Actual crewstation lighting present; out-of-crewstation lighting matches actual	Stimulus

Gawron, V.J., Bailey, R., and Lehman, E.: "Lessons Learned in Applying Simulators to Crewstation Evaluation," The International Journal of Aviation Psychology, Volume 5, Number 2, 277-290, 1995.

Simulator Features – Crewstation cont'd

Number	Feature	Definition	Fidelity
4.4	Seat/Restraints		
4.4.1	Non-representative	Seat does not have actual dimensions or seat restraints	Stimulus
4.4.2	Simulated, representative	Seat has actual dimension and seat restraints	Stimulus
4.4.3	Engineering mockup	Non-functional dimensionally accurate seat and restraints	Stimulus
4.4.4	Actual seat and restraint	Actual, functional seat and restraints are present	Stimulus

Gawron, V.J., Bailey, R., and Lehman, E.: "Lessons Learned in Applying Simulators to Crewstation Evaluation," The International Journal of Aviation Psychology, Volume 5, Number 2, 277-290, 1995.

Simulator Features – Operations

Number	Feature	Definition	Fidelity
5.1	Flight Stresses		
5.1.1	None	No additional flight stresses are present	Stimulus
5.1.2	Simulated	Flight stresses are simulated using gaming techniques	Stimulus
5.1.3	Real-world	Real-world flight stresses associated with aircraft responsibility	Stimulus
5.1.4	Actual	Real-world flight stresses associated with aircraft responsibility and complete operational conditions	Stimulus
5.2	Tasks		
5.2.1	Synthetic/experimental tasks	Artificial tasks are imposed	Response
5.2.2	Actual tasks	Actual tasks are performed to operational criteria	Response

Gawron, V.J., Bailey, R., and Lehman, E.: "Lessons Learned in Applying Simulators to Crewstation Evaluation," The International Journal of Aviation Psychology, Volume 5, Number 2, 277-290, 1995.

Instructor Support

Features	Features to facilitate training/testing
Tutorial	On-line training for the instructor
Automated measurement	Automatic calculation of time, number of trials, and errors made by each student
Briefing/debriefing	Ability to point out cues and problems
Scenario control	Automatically configure and control the simulator upon instructor selection of conditions
Initial conditions control	Instructor control (a) vehicle configuration, (b) route characteristics, (c) radio/navigation aids, (d) environmental conditions, and (e) vehicle handling characteristics
Real-time simulation variable control	Control for insertion, removal, and alteration of simulation variables while instructor is in operations. Variables shall include environmental conditions; vehicle configuration, maneuvering, and positioning
Ease of use	Ease of programming, operation, and maintenance
Malfunction control	Instructor can preprogram sequence of abnormal vehicle equipment conditions and/or emergency conditions before or during training session. Time and number of actions required on for instructor to select, alter, and enter malfunctions shall be minimized
Reposition	Capability to position the [simulator] at any point in training

Pierowicz, J., Robin, J., Gawron, V., Watson, G., Nestor, B., and Murphree, W.: "Commercial truck simulators re-assessment and evaluation," Washington, DC: Federal Motor Carrier Safety Administration, FMCSA-RT-03-008, December 2002.

Instructor Support cont'd

Instructor overview	**Provide the instructor with a meaningful depiction of student performance during active training. The presentation of information shall be an easy-to-read, uncluttered, standardized format of the current status of graphical and instructional information.**
Bird's eye view	**Enable instructor see vehicle interactions from above**
Freeze	**Allow the values of one or more simulator parameters (select system/parameters) to be frozen at any given time within a mission training scenario**
Record/replay	**Capability to record and reproduce all events, which occurred as a consequence of student, input to the simulator's controls. Recorded student events shall include control movements, instrument values, displays, motion cues, visual scenes, sounds and voice communications**
Demonstration	**Reproduce all simulated conditions including activation of vehicle cab instruments, indicators, controls, motion system movement, visual display scenes, and communications, as viewed from the cab**
Data storage	**Stored data may include information grouped by student, student type and class, the objectives attained, time/attempts to attain the objectives, and conditions under which the objectives were met or not met**
Ease of changing scenarios	**Ease of instructor to select different scenarios**

Pierowicz, J., Robin, J., Gawron, V., Watson, G., Nestor, B., and Murphree, W.: "Commercial truck simulators re-assessment and evaluation," Washington, DC: Federal Motor Carrier Safety Administration, FMCSA-RT-03-008, December 2002.

Above Real Time Training

- **Air Force Research Laboratory up to 20 times real time to train patterns of behavior to novices**
- **Enhanced dual- and multi-task performance**
- **Applied by NASA to encourage automaticity and reduce pilot workload**
- **One ARTT training session enhanced simulated flight control performance in Defence Research and Development Canada study**

Crane, P. and Guckenberger, D. Above real-time training. In O'Neil, H.F. and Andrews, D. Aircrew training and assessment. Mahwah, NJ: Lawrence Erlbaum, 2000, 153.
Donderi, D.C., Niall, K.K., Fish, K., and Goldstein, B. Above-Real-Time Training (ARTT) improves transfer to a simulated flight control task. Human Factors, 2012, 54(3), 469 – 479.

Agenda

- 11:00 to 12:00
  - Human Factors Analyses in Simulation for Training
    - Curriculum Evaluation
    - Transfer of Training
- 1:00 to 2:00
  - Traditional Types of Simulators Used in Training
    - Static Mockups
    - Dynamic Mockups
    - Part Task Simulators
    - Full Mission Simulators
    - In-flight Simulators
  - Nontraditional Types of Simulators Used in Training
    - Distributed Network of Dissimilar Simulations
    - Virtual Reality
    - Flatworld
    - Embedded Training
    - Cell Phones
    - iPod
    - Gaming
    - Weightlessness Simulators

Microsoft clip art

Types of Simulators

- **Traditional Types of Simulators Used in Training**
  - **Large body of research**
  - **Standard interfaces and functionality**
  - **Available instructional packages**
  - **Technology to enhance processing speed and visuals**
- **Nontraditional Types of Simulators Used in Training**
  - **Limited body of research**
  - **Limited standardization in either interface or functionality**
  - **Custom built instructional packages**
  - **Technology to enhance processing speed, visuals, auditory cues, haptic cues**

Traditional Types of Simulators Used in Training

- Static Mockups
- Dynamic Mockups
- Part Task Simulators
- Full Task Simulators
- Full Mission Simulators
- In-Flight Simulators

Microsoft clip art

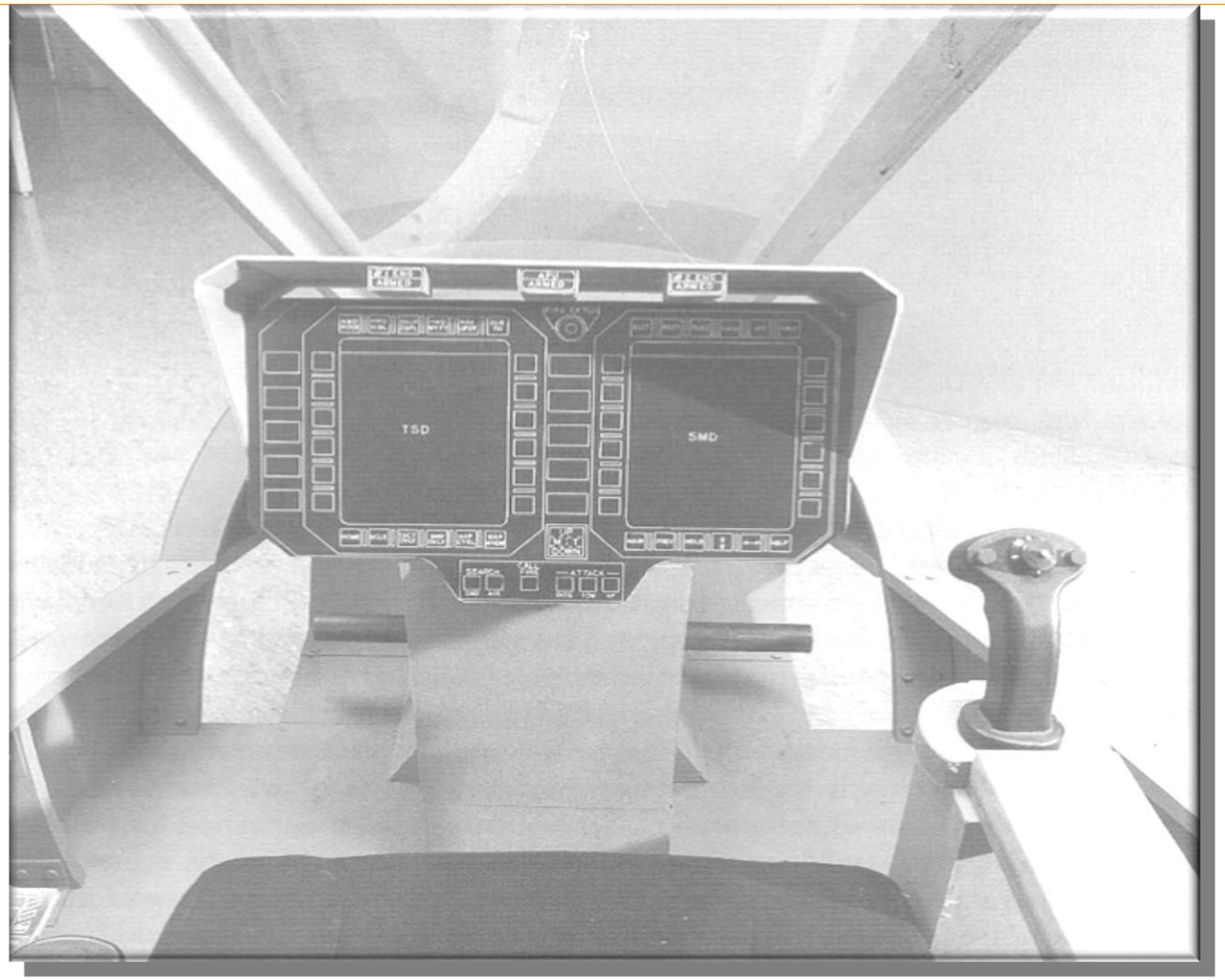
Static Mockups

Microsoft clip art

- **Definition - a three-dimensional (3-D) model of a product or system that has no moving parts**
- **Range from an individual control, such as an airplane control yoke, to an entire vehicle control station**
- **Types**
  - **Foam core - a thin sheet of dense StyrofoamTM (usually 1/8 or 3/16 inch thick), covered with white paper**
  - **Wood**
  - **Plastic - stereolithography uses 3-dimensional solid CAD data to build parts from a liquid photopolymer resin that solidifies when exposed to a high-radiance light source**

Gawron, V. J., Dennison, T W., and Biferno, M. A.: "Mockups, Models, Simulations, and Embedded Testing." In S.G. Charlton and T.G. O'Brien (Eds.) Handbook of Human Factors Testing and Evaluation Second Edition, Mahwah, New Jersey: Lawrence Erlbaum Associates, 2002.

Example of a Static Mockup



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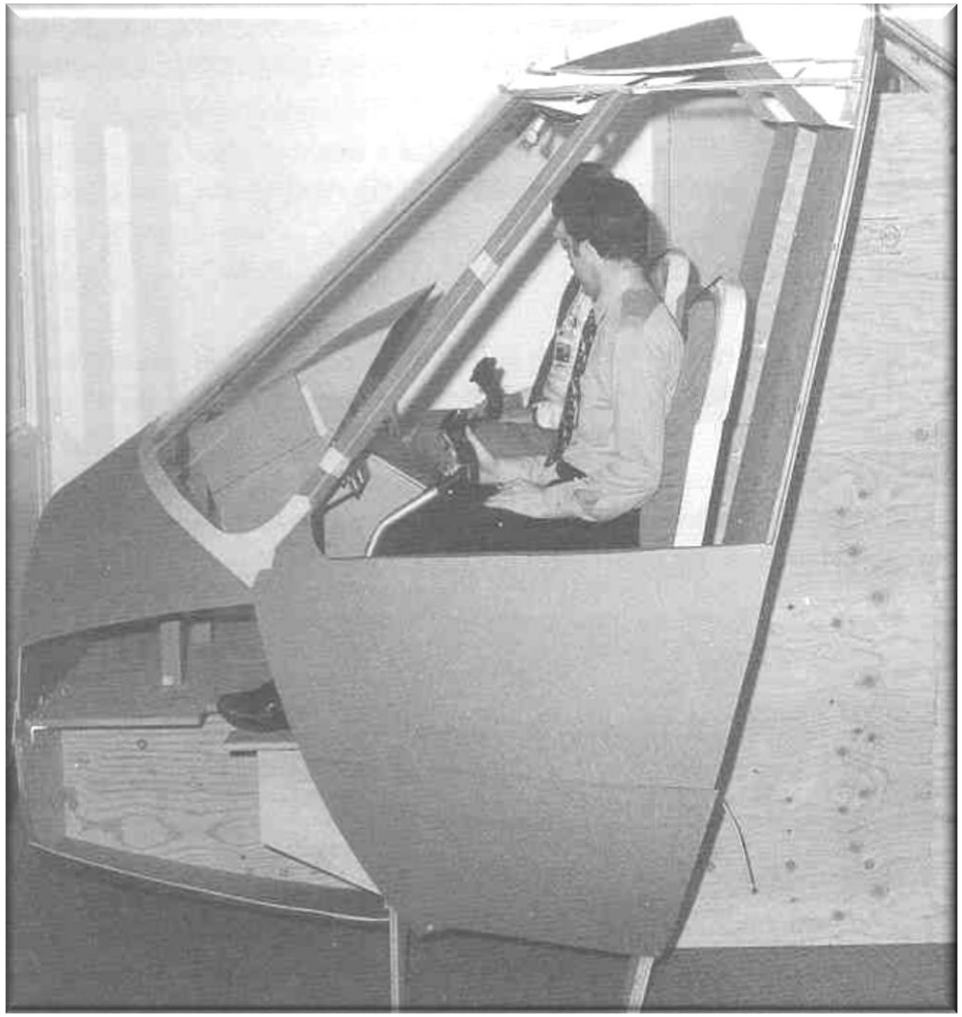
Dynamic Mockups


Microsoft clip art

- **Definition - a three-dimensional (3-D) model of a product or system with no moving parts and no functionality**
- **Range in scope from an individual control, such as an airplane control yoke, to an entire vehicle control station**
- **Types**
  - **Wood**
  - **Plastic - stereolithography uses 3-D CAD data to build parts from a liquid photopolymer resin that solidifies when exposed to high-radiance light**
  - **Hardware to emulate moving parts such as controls and seat restraints**

Example of a Dynamic Mockup



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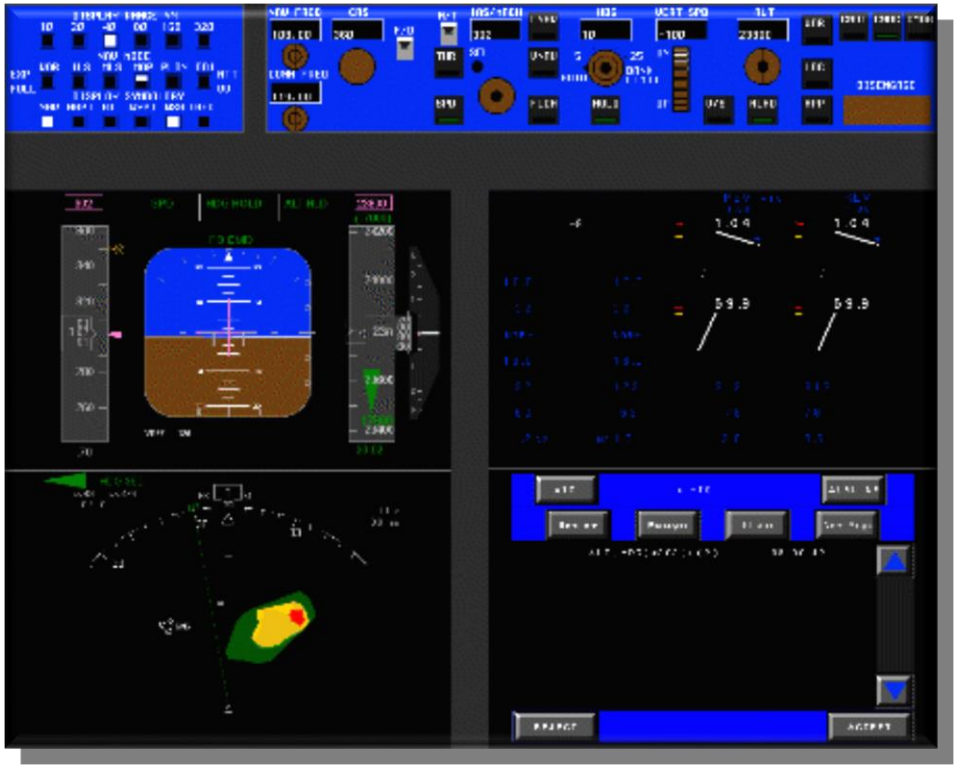
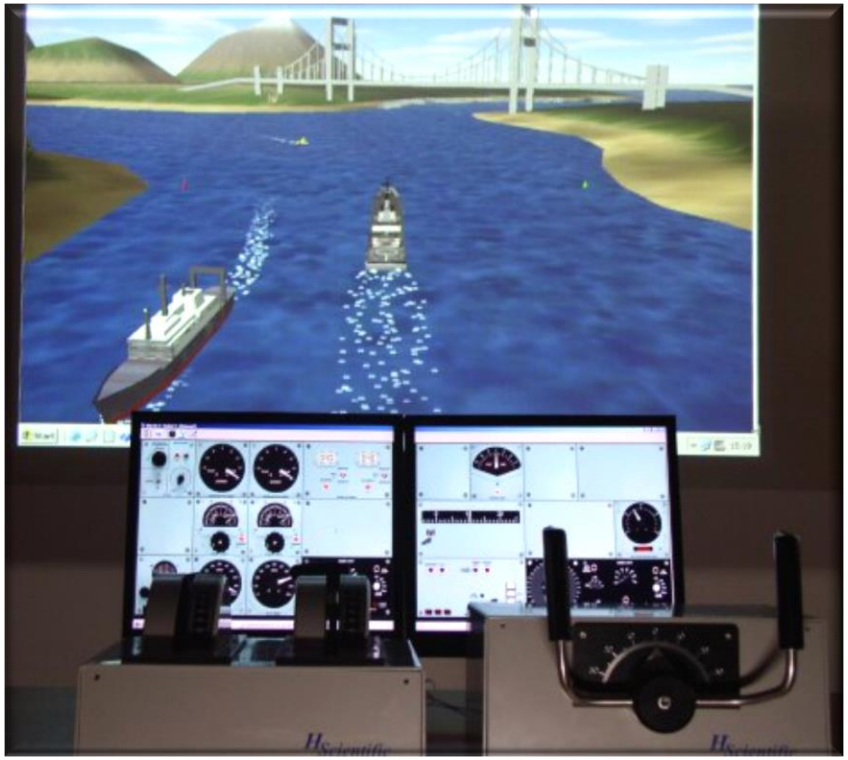
Part Task Simulators

Simulate a specific aspect of the task for training

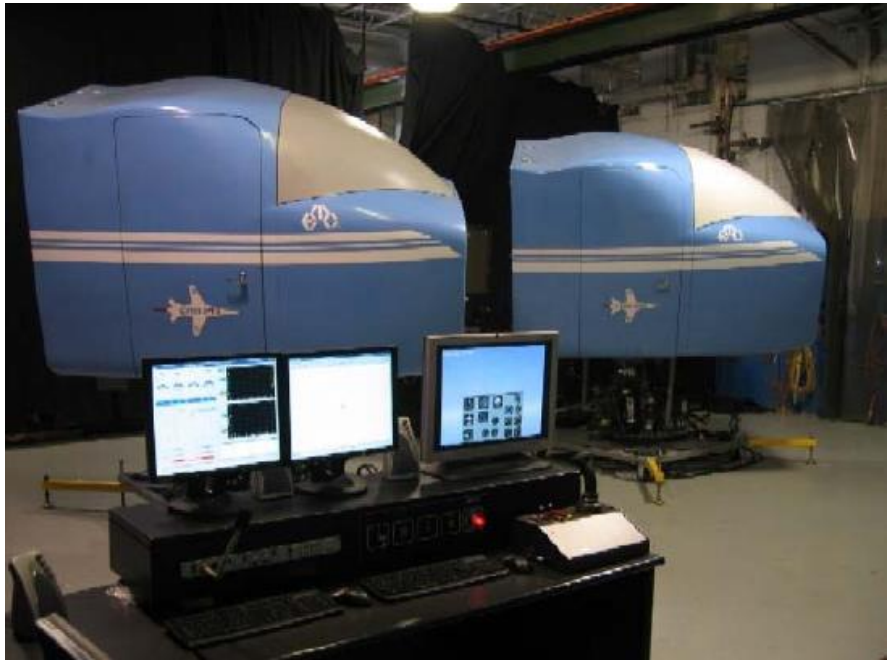




http://human-factors.arc.nasa.gov/IHpublications/pisanich/part-task/part-task-paper.html

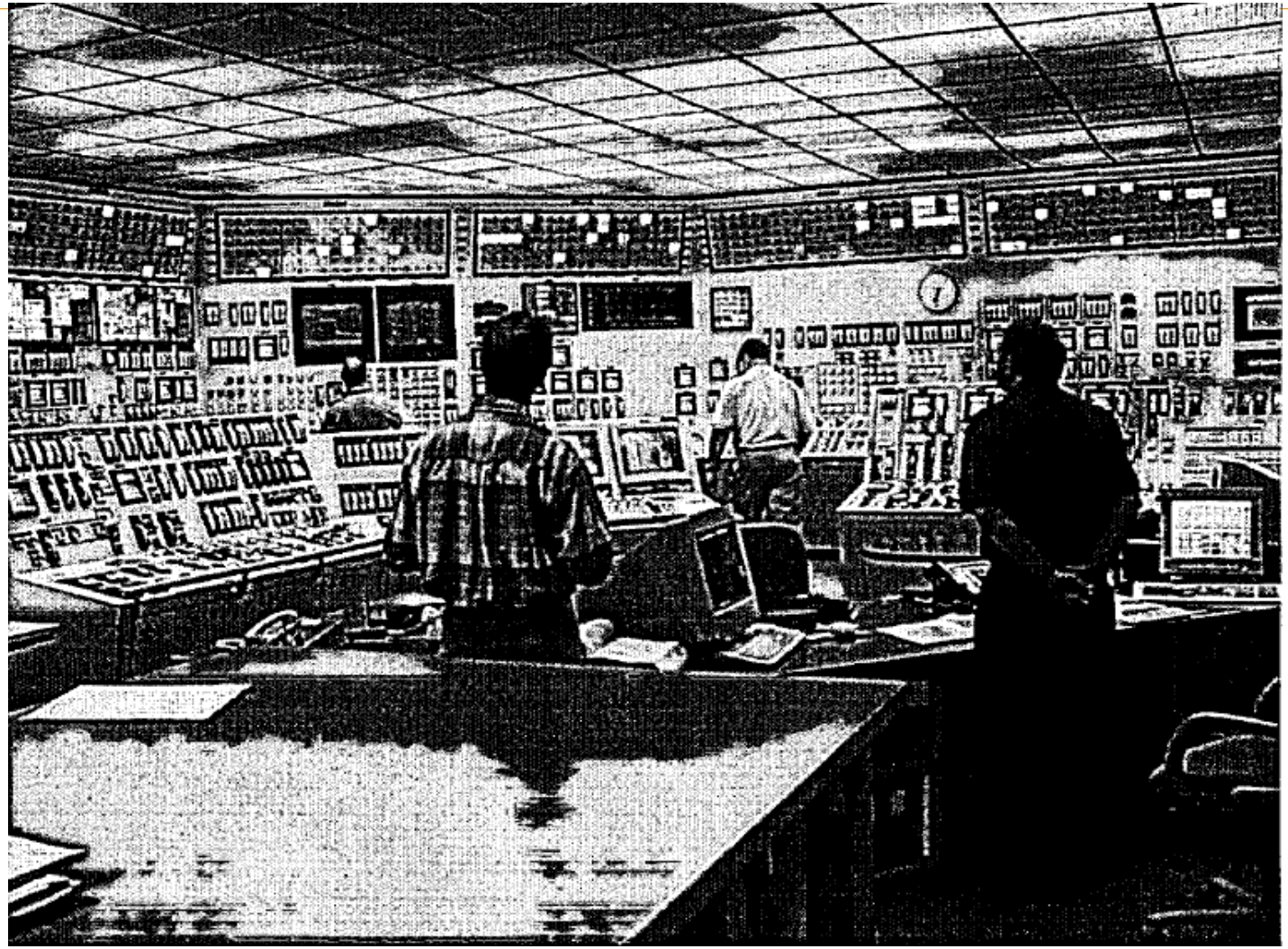
Spatial Disorientation Trainer

- Graveyard spin
- Graveyard spiral
- The Leans
- Elevator illusion
- False vertical and horizontal cues
- Coriolis illusion
- Oculogravic and Oculogyral illusions
- Inversion illusion
- Somatogravic and Somatogyral illusions
- Confusion of light sources in night flight conditions (autokinesis)



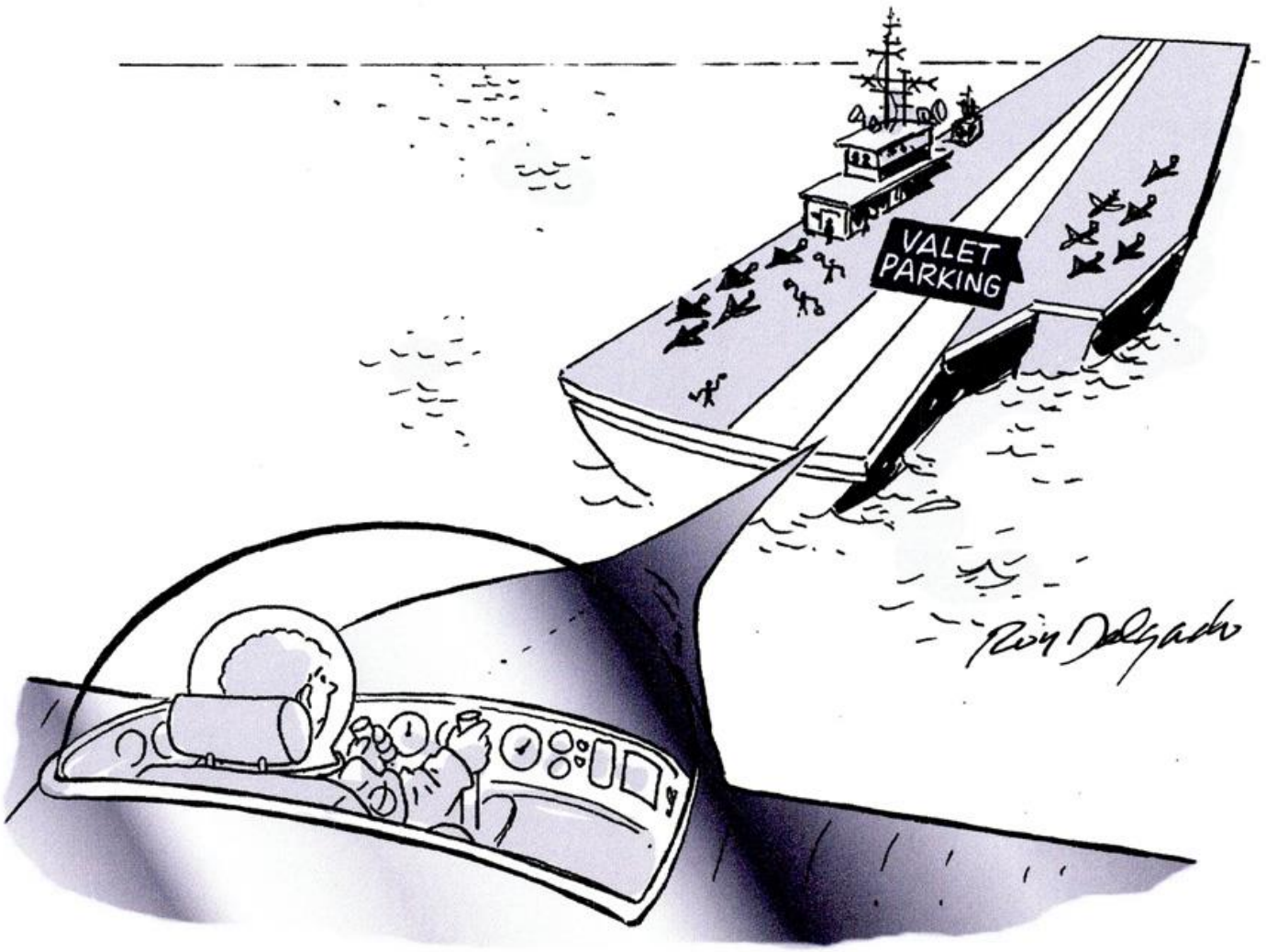
www.public.navy.mil/navsafecen/Documents/aviation/aeromedical/Articles_Info/full%20natoSD.pdf

Nuclear Power Plant



http://pbadupws.nrc.gov/docs/ML9934/ML993400477.pdf

Need for Part Task Simulator



Source: www.CartoonStock.com

Part-mission Simulators

Simulate a specific part of the mission for training

DefenseImagery.mil

Courtesy US Navy

Joint Fires and Effects Trainer System

Courtesy US Army

Changes in Part-mission Simulators

Courtesy US Navy

Full Mission Simulators

- **Simulate all tasks from start to end of mission:**
  - **Landing, takeoff, weapons delivery, night flight, formation flight, and cockpit familiarization in normal, adverse, and emergency situations**
- **Recreate sounds, motion, visual scenes, instrument presentations and all other systems**
- **Represent actual aircraft characteristics based on available flight data and input from experienced pilots**
- **Most full mission simulators are for aircraft**

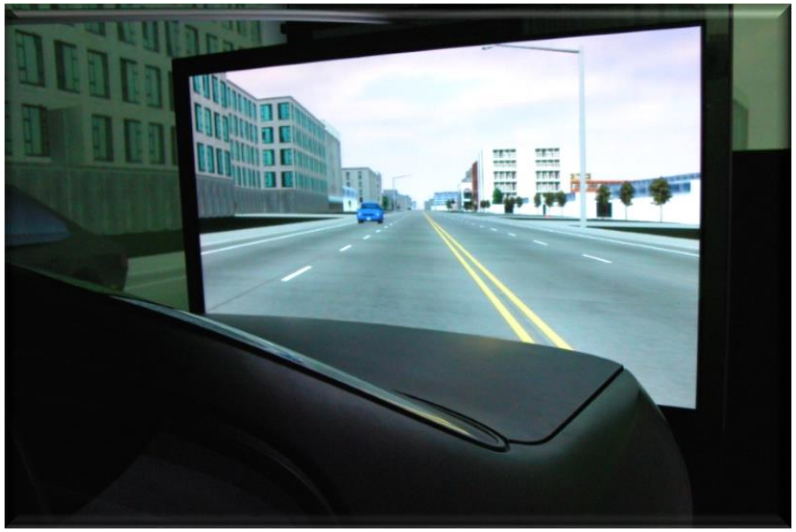
http://www.cae.com/en/military/flight/products/fms.shtml

Frasca International

EC225 Full Flight Simulator

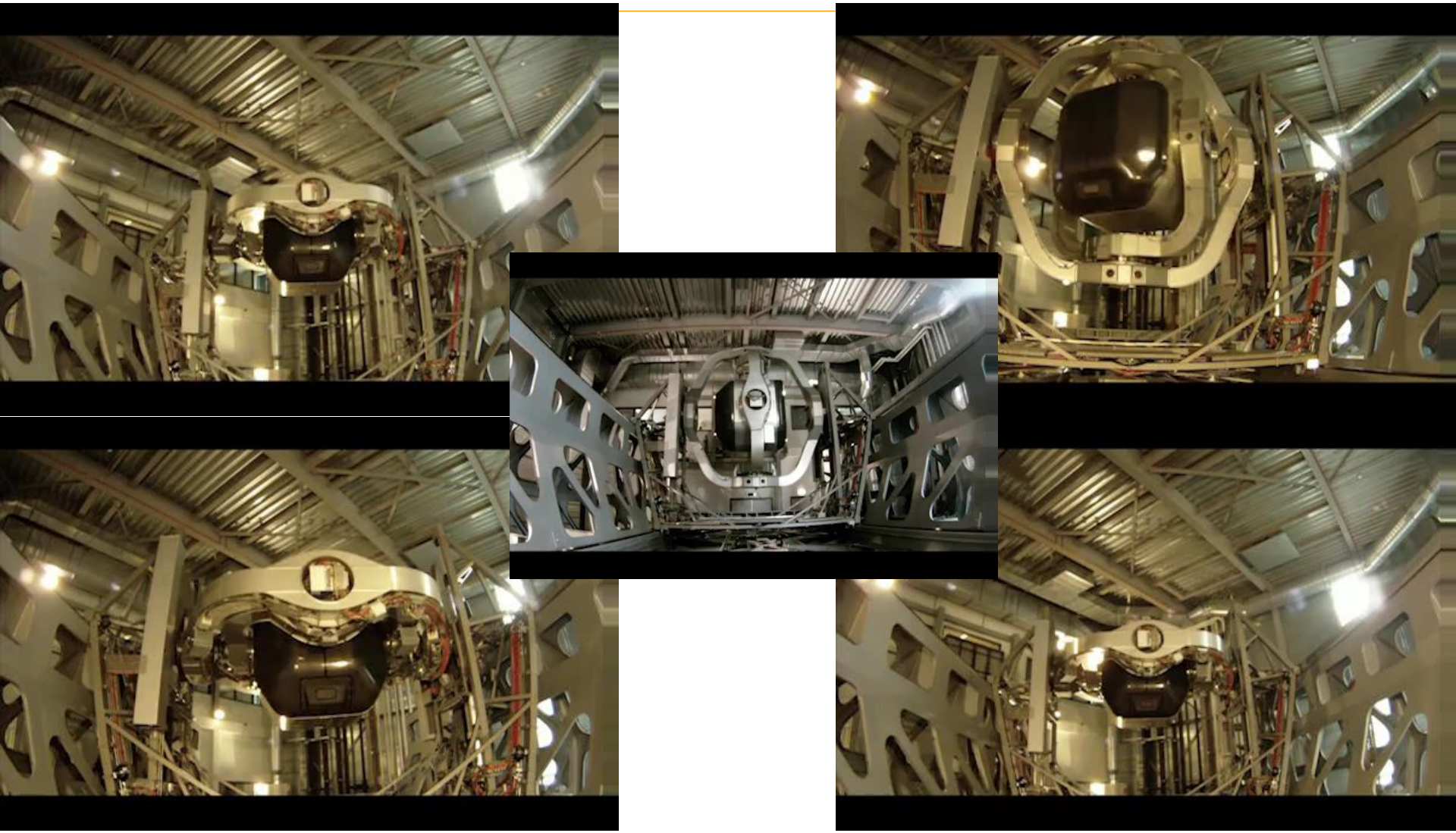
photo courtesy of Frasca International, Inc.

National Advanced Driving Simulator



Courtesy NHTSA

Desdemona



Courtesy TNO

Farming Simulator – John Deere

Courtesy John Deere

In-Flight Simulator

- Ground simulator that flies
- Replicates another aircraft's dynamic response with cockpit controller force-versus-position
- Replicates cockpit displays
- Computer control of all six degrees of freedom including response to air turbulence

Gawron, V.J. and Reynolds, P.A. "When In-Flight Simulation is Necessary," Journal of Aircraft, Volume 32, Number 2, 1995, 411-415

Total In-Flight Simulator (TIFS)

Courtesy US Air Force

TIFS Synthetic Vision

Courtesy NASA

Variable Stability In-Flight Simulation Test Aircraft (VISTA)

Courtesy US Air Force

Lear 24 and 25

Courtesy US Air Force and Calspan

Nontraditional Types of Simulators Used in Training

- Distributed Mission Trainers
- Virtual Reality
- Embedded Training
- Cell Phones
- iPod
- Gaming
- Weightlessness Simulators

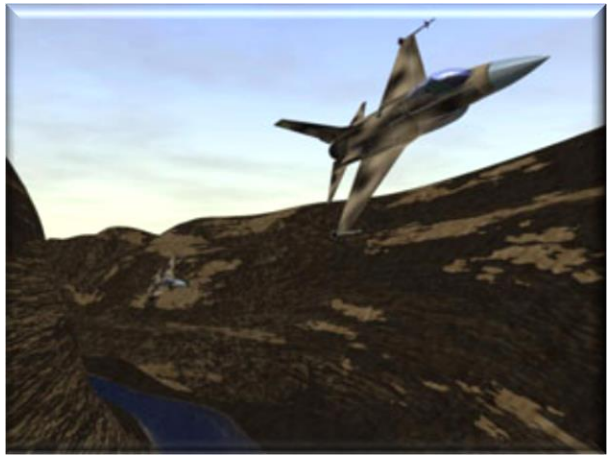
Microsoft clip art

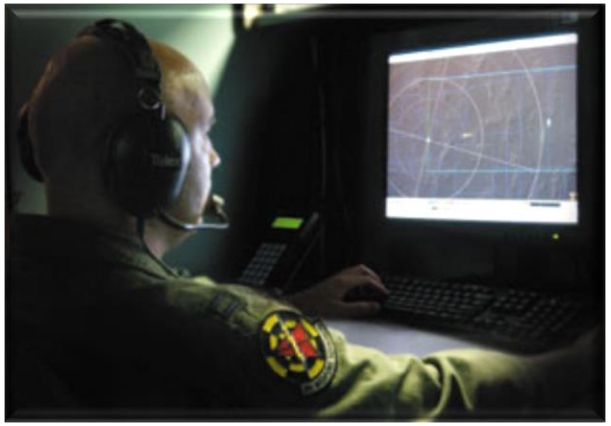
Distributed Mission Trainers

- **Individual simulators in different locations simulate same environment**
  - **Pilot flying fighter aircraft simulator sees tank controlled by soldier in tank simulator in different location**
  - **Current state of the art in training simulation**

http://www.mesa.afmc.af.mil/learningmanagement.html

Air Force Research Laboratory Distributed Mission Trainer

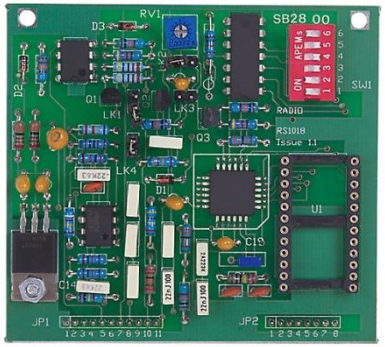




Air Force Research Laboratory Mesa, AZ

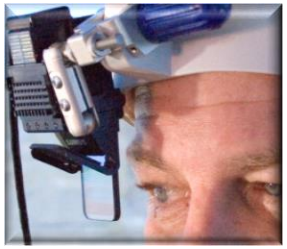
Virtual Reality

- **Computer simulations to enable user to interact with a virtual environment**
- **Types of virtual reality training simulations**
  - **Augmented Reality**
  - **Digitally Enhanced Mannequins**
  - **Data Glove**
  - **Head Mounted Display**
  - **Flat World**
  - **Second Life**

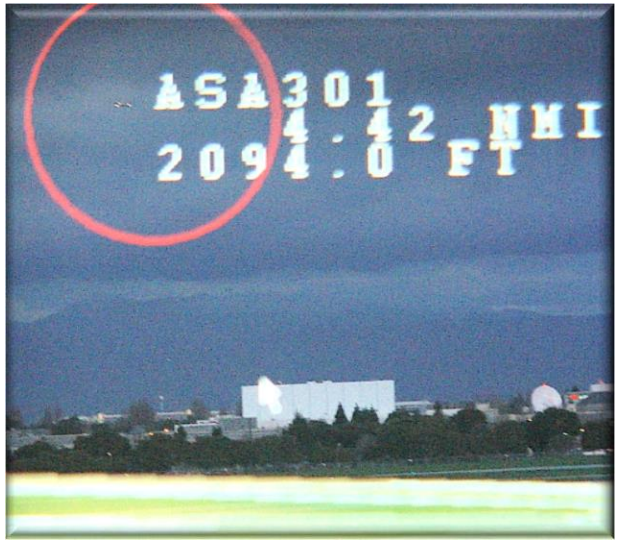


Microsoft clip art

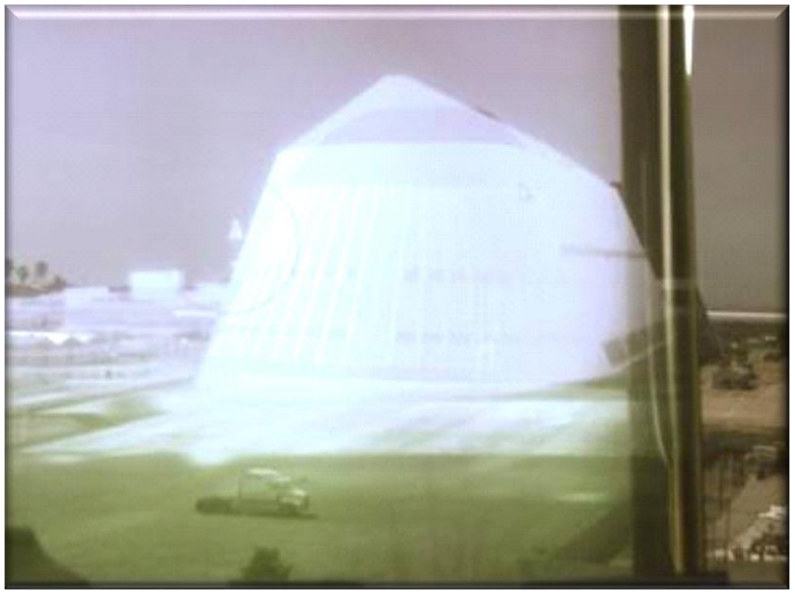
Augmented Reality Tower Tools (ARTT)



Monocle



Data block and the circle are projected on aircraft



3-D optical images are projected on top of the actual objects

Courtesy: Reisman, NASA

Theodolite iPhone App

http://hrtapps.com/pr/

Digitally Enhanced Mannequins

- **iStan - moves, breathes, lives and dies**
- **Self contained, wireless**
- **Fluids**
- **Articulated motion**
- ***Grey's Anatomy* - original episode aired November 6 at 9 p.m. EST on ABC**

https://caehealthcare.com/home/eng/product_services/product_details/hps-human-patient-simulator#

Data Glove

http://www.mesa.afmc.af.mil/gose.html

Head Mounted Display

http://www.army.mil/media/258435/

Flat World

http://www.ict.usc.edu/disp.php?bd=proj_flatworld

Virtual Humans

Institute for Creative Technologies

Embedded Training

- **Training in operational systems to enhance and maintain skill proficiency**
- **Enables training delivery to operators using their own equipment while in the field or home station**
- **Enhances or maintains skill proficiency by enabling trainees to use operational equipment**

Digital Divisions 2 Through N (DD2-N) ABCS Training Sub-System Architecture (ATSA) Functional Capability Description (FCD), Version 1.0, 1 August 2000, Prepared by: The MITRE Corporation, 1820 Dolly Madison Blvd., McLean, VA 22102

Example of Embedded Training

http://www.chinfo.navy.mil/navpalib/policy/fromsea/pos98/45.gif

Cell Phones as Simulators

- **Army Acquisition Command's Program Executive Office for Simulation, Training and Instrumentation**
- **Primarily for remote military units abroad**
- **Current training applications: maintenance technicians for weapons and aircraft, riflery students, and mission planners**
- **Mission planners navigate with arrows and zoom functions through 3-D, computer-aided-design maps of cities and buildings**

Cell Phone Example - Mission Rehearsal

Courtesy US Air Force

iPOD

DefenseImagery.mil

Gaming

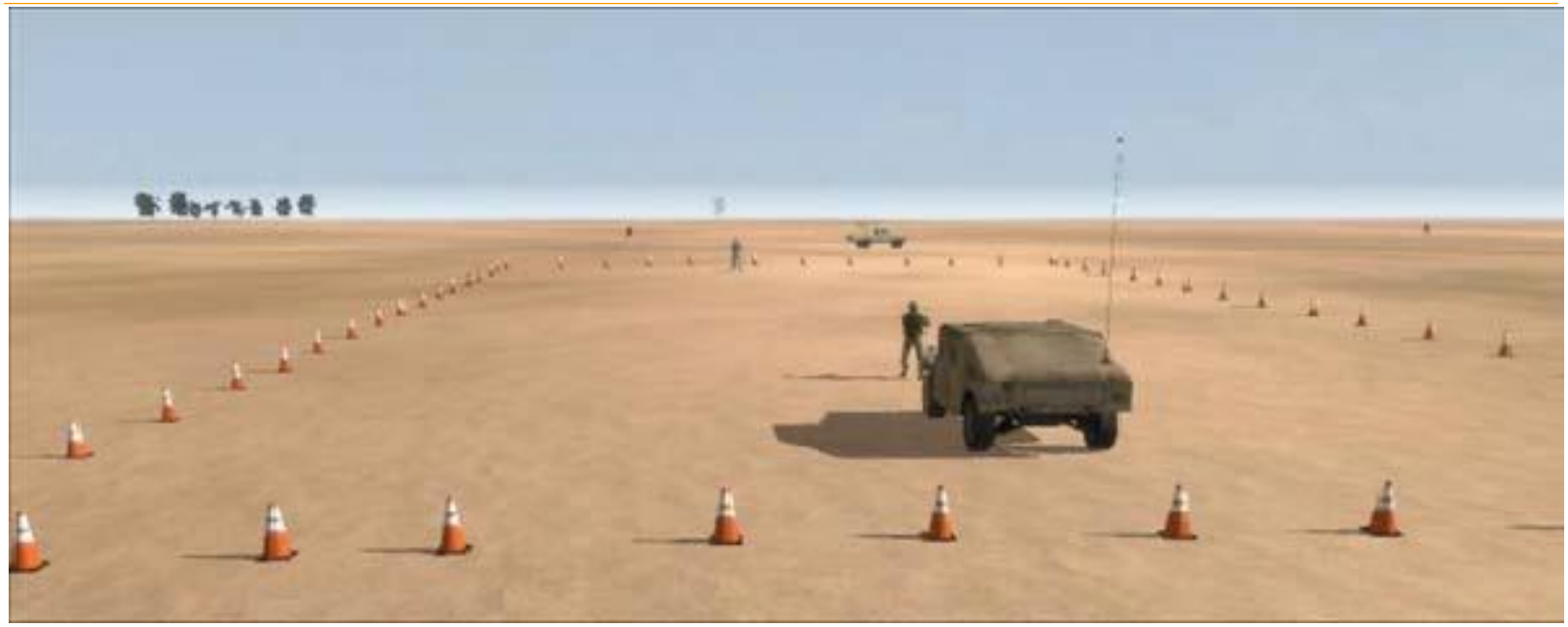
- Definition - use of video games to train personnel
- Examples
  - Canon and Cisco use video games to teach technical skills such as equipment repair and network maintenance
  - e=mz2 developed a video game for sales people to trying to win over a client
- Advantages
  - Efficient
  - Highly addictive

Microsoft clip art

Gaming Examples

Courtesy US Army

Virtual Battlespace 2™



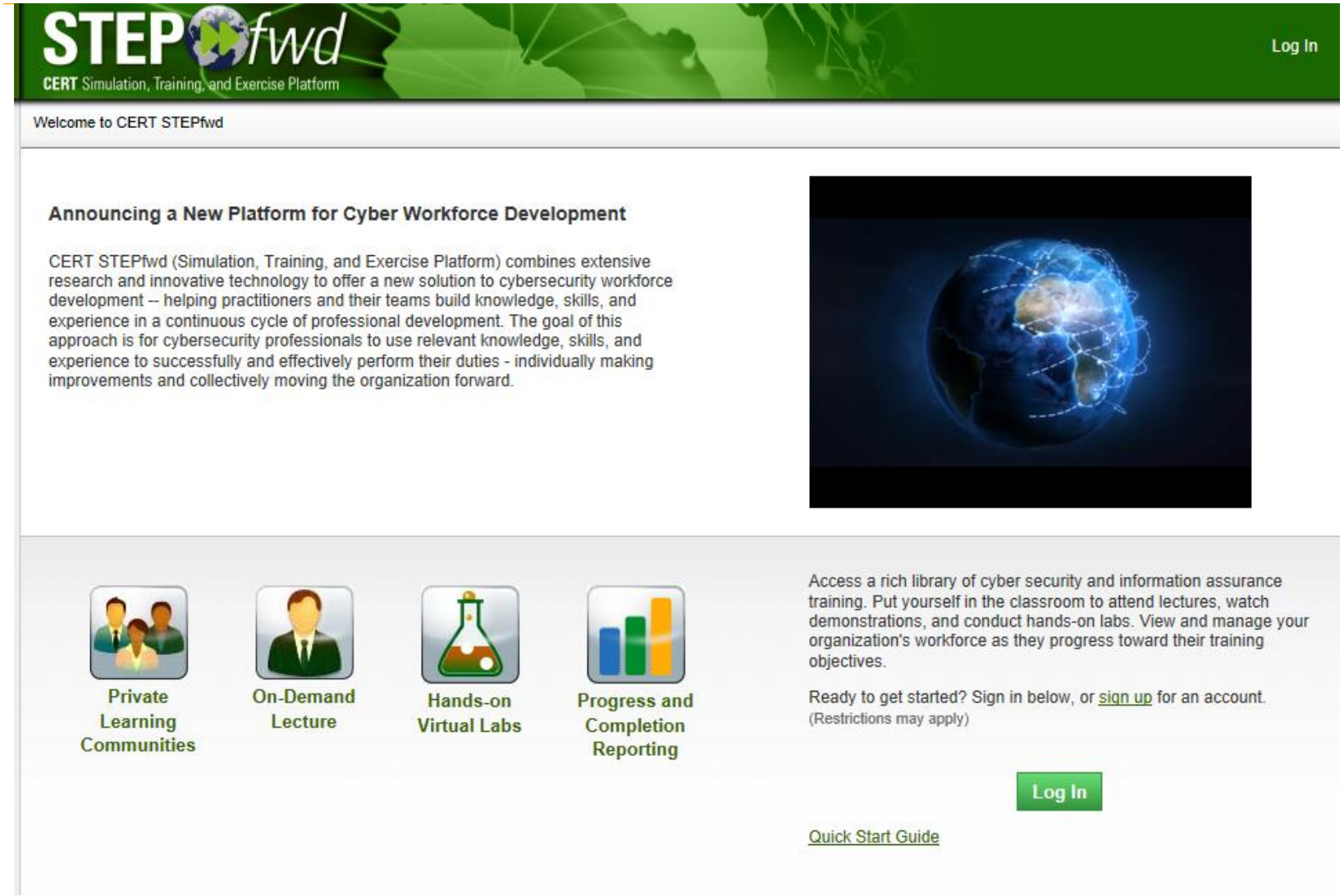
Brown, B.: “A transfer of training study of simulation games,” Monterey, California: Naval Postgraduate School, March 2010.

Most Successful Game – America's Army

Courtesy US Army

Air Force Recruiting

STEPfwd



https://stepfwd.cert.org/vte.lms.web

Virtual Air Traffic Simulation Network

http://www.vatsim.net

GlassLab

Transforming learning and formative assessment through digital games

http://glasslabgames.org/

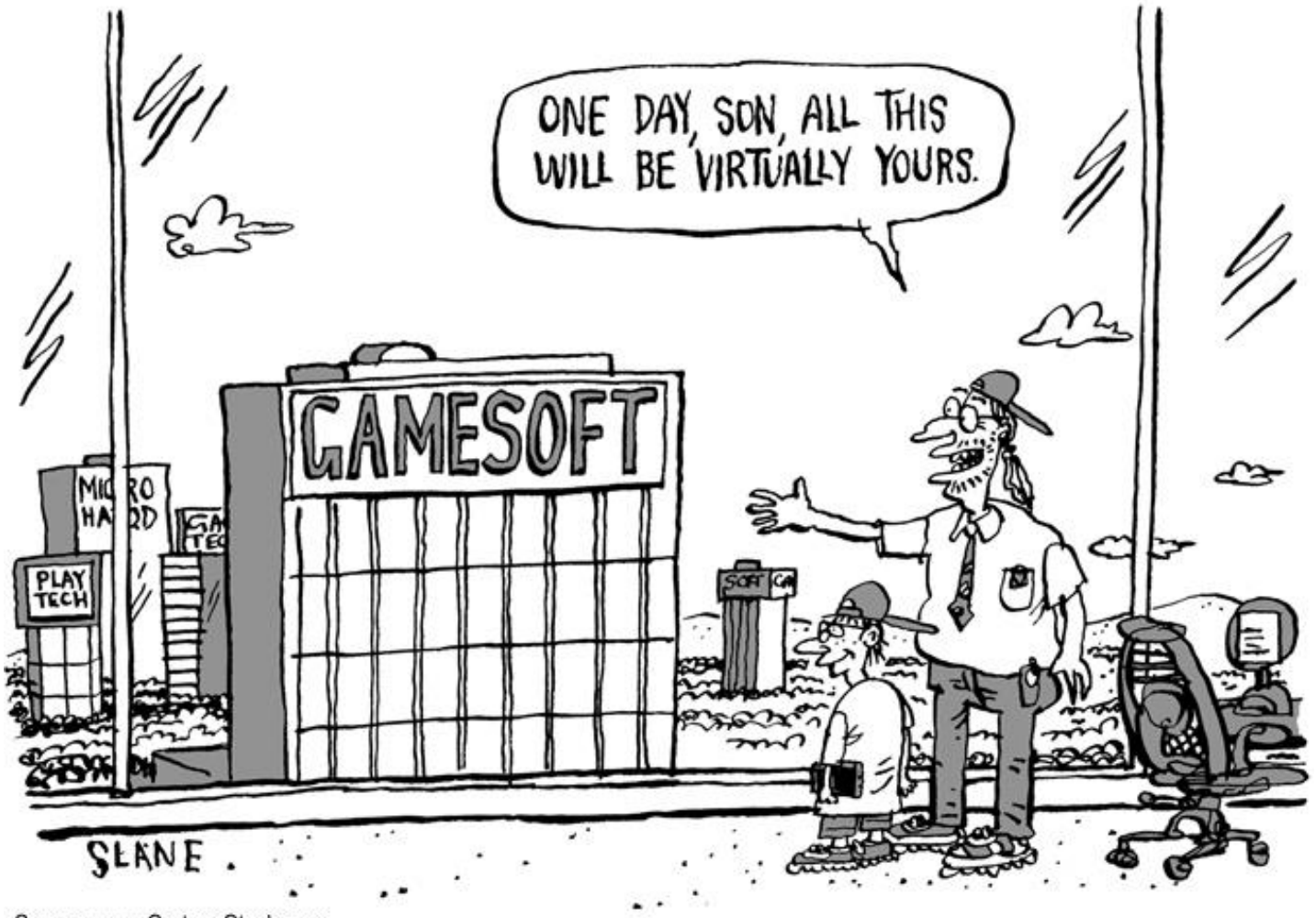
Quest Atlantis

http://atlantisremixed.org/

Massachusetts Institute of Technology
Open Courseware

http://ocw.mit.edu/index.htm

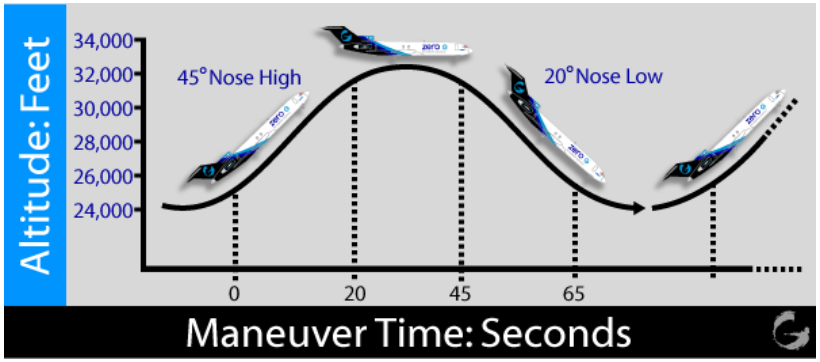
Gaming

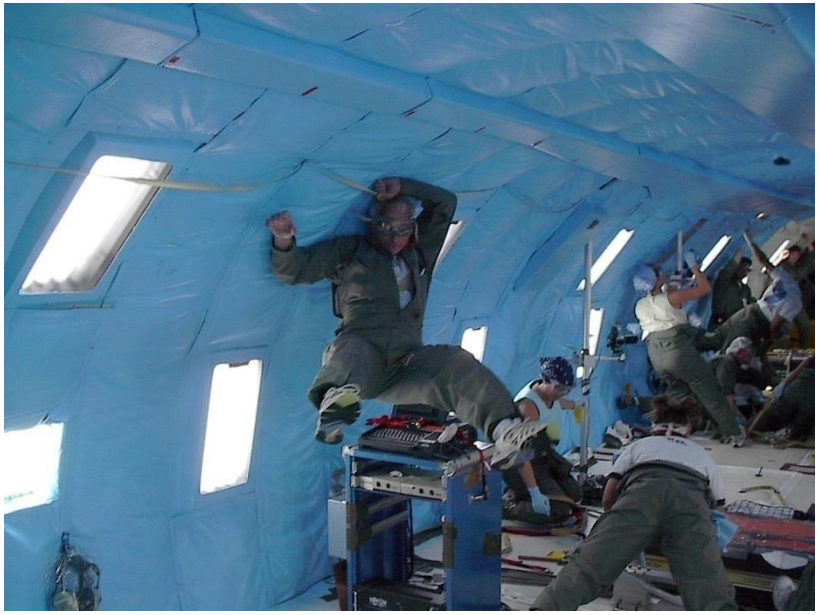


Source: www.CartoonStock.com

Weightlessness - Zero G

- **1/3/08 NASA awarded Zero Gravity contract to provide parabolic flights**
- **Boeing 727 aircraft named G-FORCE ONE**
- **Flown between 24,000 and 34,000 feet AGL**
- **Each parabola takes 10 miles of airspace**
- **Weightlessness lasts one minute**
- **http://www.gozerog.com/**

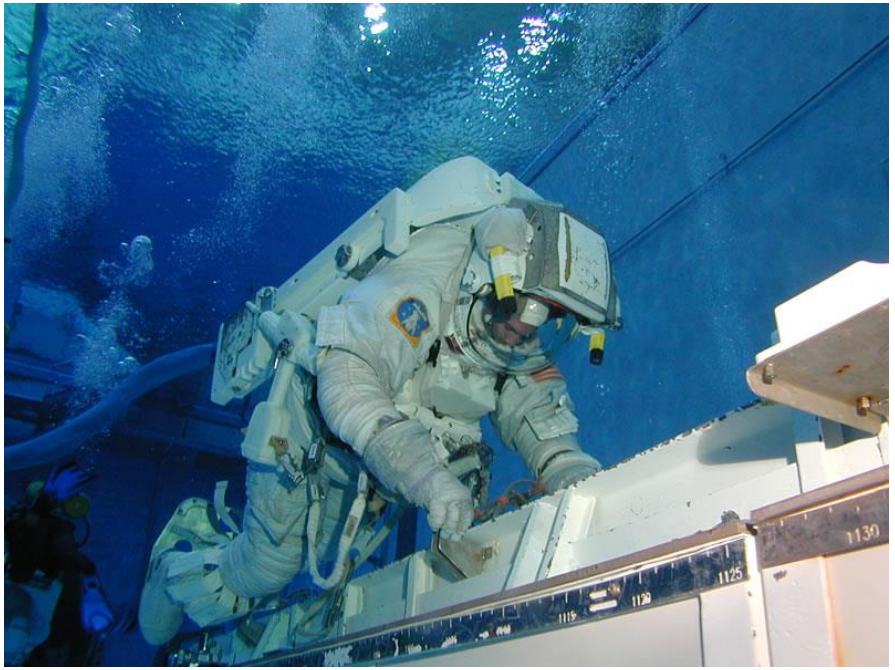




Dr. Brian Peacock with permission

Weightlessness - Neutral Buoyancy Laboratory (NBL)

- **Sonny Carter Training Facility at NASA Johnson**
- **Largest indoor pool of water in the world**
- **Contains full-sized mock-ups of Space Shuttle cargo bay, flight payloads, and International Space Station**
- **Astronauts perform simulated Extra-vehicular activity (EVA) tasks**



Courtesy NASA Johnson

It’s Only A Paper Moon …

- **I never feel a thing is real**
  When I'm away from you
  Out of your embrace
  The world's a temporary parking place

  Mmm, mm, mm, mm
  A bubble for a minute
  Mmm, mm, mm, mm
  You smile, the bubble has a rainbow in it

  Say, its only a paper moon
  Sailing over a cardboard sea
  But it wouldn't be make-believe
  If you believed in me

- **Yes, it's only a canvas sky**
  Hanging over a muslin tree
  But it wouldn't be make-believe
  If you believed in me

  Without your love
  It's a honky-tonk parade
  Without your love
  It's a melody played in a penny arcade

  It's a Barnum and Bailey world
  Just as phony as it can be
  But it wouldn't be make-believe
  If you believed in me

music by Harold Arlen; lyrics by E.Y. (Yip) Harburg

There's Always Lots Of Behind The Scenes Clutter …

iStockPhoto

There're Always Lots Of Computations

- $(1+x)^n = 1 + \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} + \cdots$
- $f(x) = a_0 + \sum_{n=1}^{\infty} \left(a_n \cos\frac{n\pi x}{L} + b_n \sin\frac{n\pi x}{L} \right)$
- $e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots, \ -\infty < x < \infty$
- $\sin\alpha \pm \sin\beta = 2\sin\frac{1}{2}(\alpha \pm \beta)\cos\frac{1}{2}(\alpha \mp \beta)$
- $\cos\alpha + \cos\beta = 2\cos\frac{1}{2}(\alpha + \beta)\cos\frac{1}{2}(\alpha - \beta)$
- $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
- $A = \pi r^2$

Did I Mention Viruses?

"It appears to be some sort of computer virus."

Sometimes People Have To Learn The Hard Way

source: istockphoto

There Are Some Low Probability Events That Shouldn't Be Simulated

Courtesy US Air Force

Low Fidelity Simulators Come In Handy

But Things Are Getting Better

Questions?

Microsoft clip art