Workload as a Performance Shaping Factor in MIDAS v5

Brian F. Gore[1], Becky L. Hooey[1], Christopher D. Wickens[2], Connie Socash[2], Mala Gosakan[2], Marc Gacy[2], Mark Brehon[2], David C. Foyle[3]
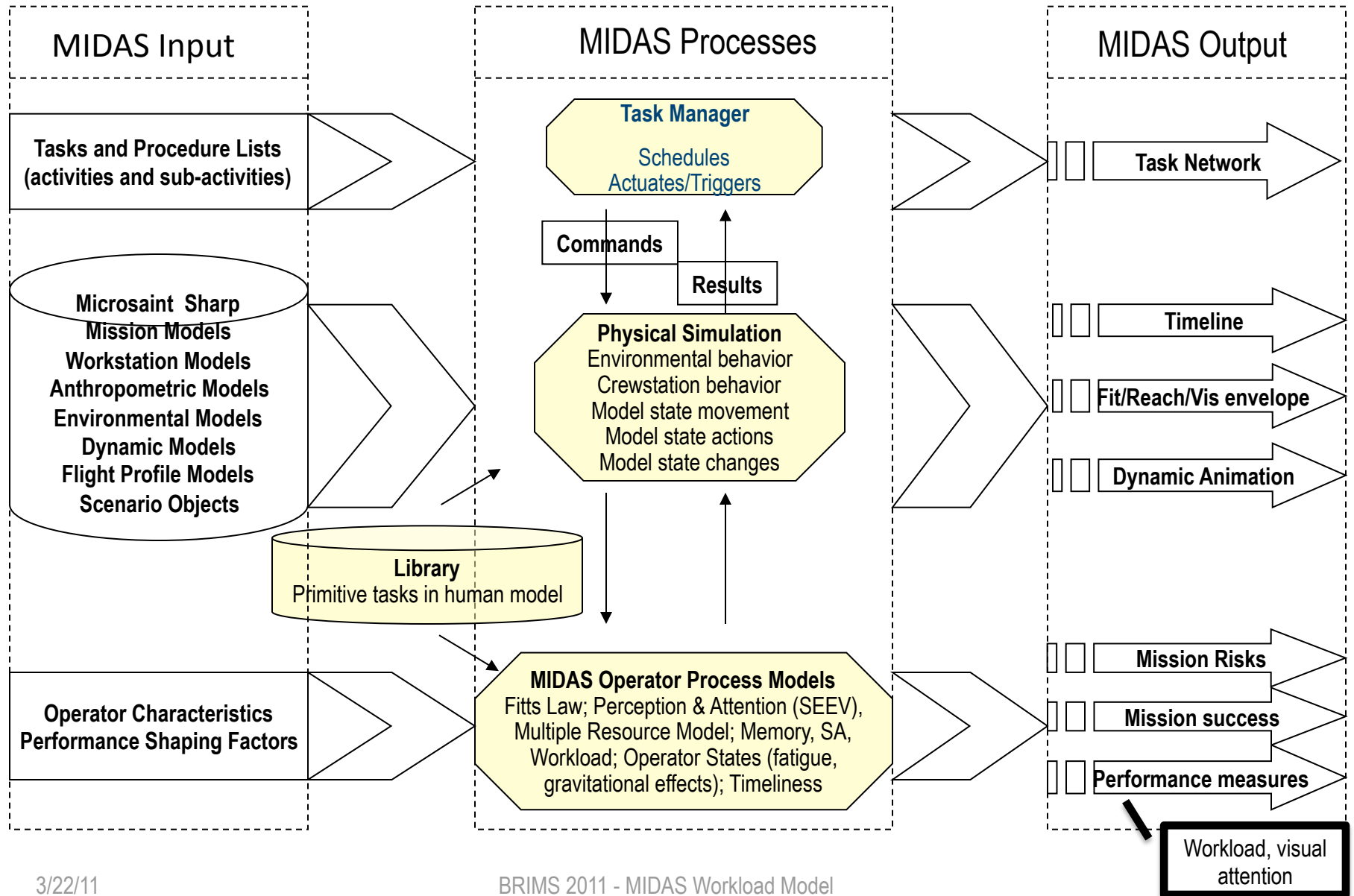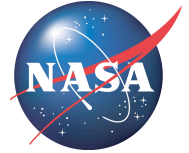
March 26, 2011

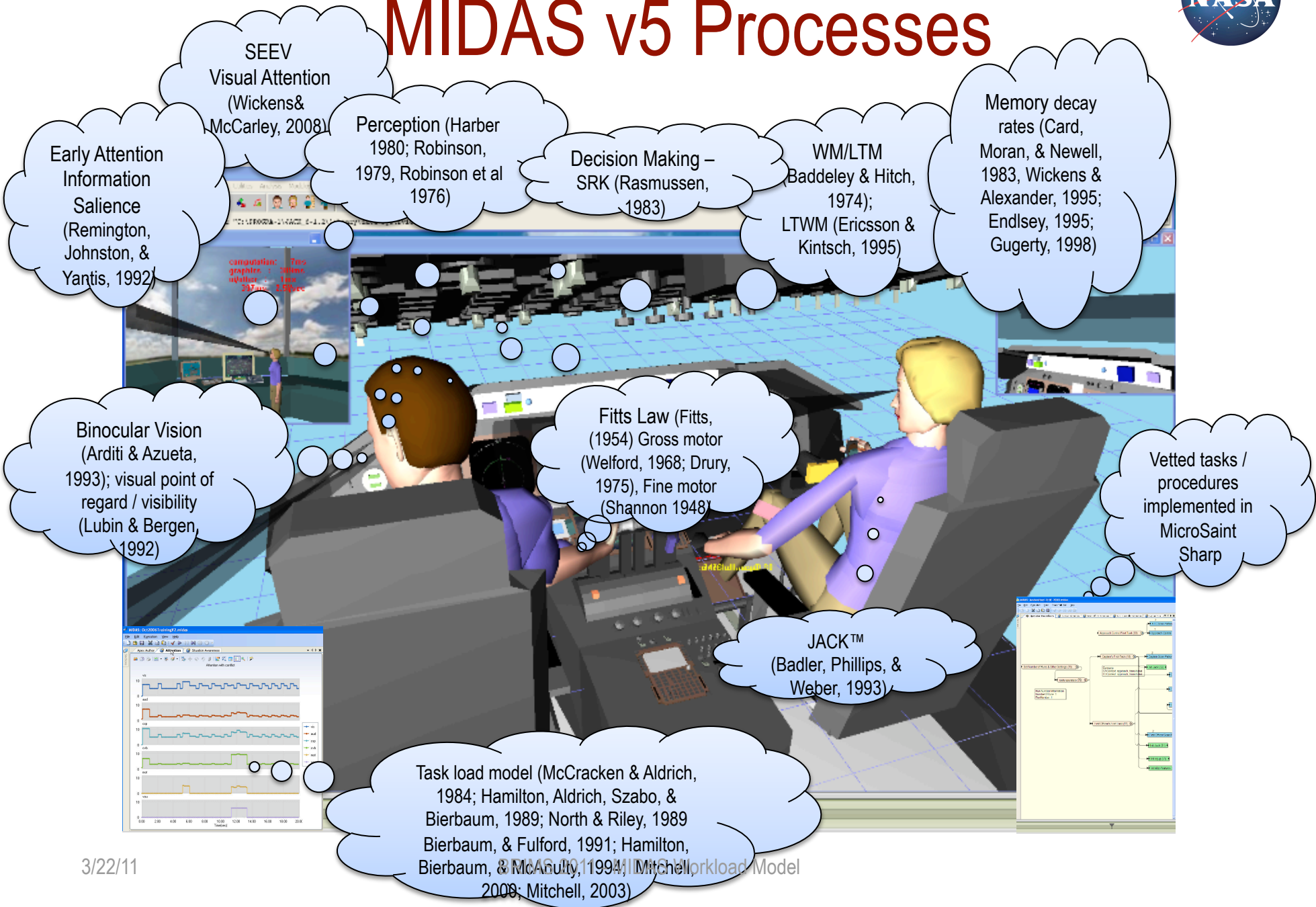Behavioral Representation in Modeling and Simulation 2011

MIDAS v5 Structures

Human Systems integration division

NASA

MIDAS Input

Tasks and Procedure Lists (activities and sub-activities)

Microsaint Sharp
Mission Models
Workstation Models
Anthropometric Models
Environmental Models
Dynamic Models
Flight Profile Models
Scenario Objects

Operator Characteristics
Performance Shaping Factors

MIDAS Processes

Task Manager
Schedules
Actuates/Triggers

Commands

Results

Physical Simulation
Environmental behavior
Crewstation behavior
Model state movement
Model state actions
Model state changes

Library
Primitive tasks in human model

MIDAS Operator Process Models
Fitts Law; Perception & Attention (SEEV), Multiple Resource Model; Memory, SA, Workload; Operator States (fatigue, gravitational effects); Timeliness

MIDAS Output

Task Network

Timeline

Fit/Reach/Vis envelope

Dynamic Animation

Mission Risks

Mission success

Performance measures

Workload, visual attention

MIDAS v5 Processes

SEEV Visual Attention (Wickens& McCarley, 2008)

Perception (Harber 1980; Robinson, 1979, Robinson et al 1976)

Decision Making – SRK (Rasmussen, 1983)

WM/LTM Baddeley & Hitch, 1974); LTWM (Ericsson & Kintsch, 1995)

Memory decay rates (Card, Moran, & Newell, 1983, Wickens & Alexander, 1995; Endlsey, 1995; Gugerty, 1998)

Early Attention Information Salience (Remington, Johnston, & Yantis, 1992)

Binocular Vision (Arditi & Azueta, 1993); visual point of regard / visibility (Lubin & Bergen, 1992)

Fitts Law (Fitts, (1954) Gross motor (Welford, 1968; Drury, 1975), Fine motor (Shannon 1948)

Vetted tasks / procedures implemented in MicroSaint Sharp

JACK™ (Badler, Phillips, & Weber, 1993)

Task load model (McCracken & Aldrich, 1984; Hamilton, Aldrich, Szabo, & Bierbaum, 1989; North & Riley, 1989 Bierbaum, & Fulford, 1991; Hamilton, Bierbaum, & McAnulty, 1994; Mitchell, 2000; Mitchell, 2003)

Workload defined

- Relationship between attentional resource demands of tasks and performance in addition to the physical task demands[1]

- Little doubt that workload impacts performance, less agreement on precisely how workload influences performance

- Often defined as task load (# of ongoing tasks)

[1]Moray, 1979, Gopher and Donchin 1986; Sarno & Wickens, 1995

MIDAS Behaviors

- Breaks tasks down to a set of basic behavioral *primitives*

  – Operator Primitives (OP) and User-defined Primitives (UP)

  – 10 OPs represent non domain-specific human behaviors (e.g., reach, push and release, say message, information seeking)

  – UPs are tailored to the domain (e.g., acquire lead aircraft).

  – In both cases, the Task Analysis / Workload (TAWL [1,2]) is used as the basis for the task loads

    - US military personnel in the Army Light Helicopter Experimental (LHX) Program[1], further tested / validated using Army tank operators[3]

[1] McCracken & Aldrich, 1984; [2] Hamilton & Bierbaum, 1992; [3] Mitchell, 2000

MIDAS Workload Model

- Computes the workload of a multi-tasking operator using the MIDAS behavioral primitives with the Multiple Resources Theory (MRT[1]) when multiple tasks share resources
  - Interference increases with the resource demands of one or both of the time-shared tasks
  - Task pair is penalized according to the conflict between tasks on resource pairs
- Conflict matrix – the amount of conflict between resource pairs across tasks
  1. Combines a conflict matrix and task degradation functions, MIDAS completes the tasks and outputs workload without a limit on task performance, predicts workload spikes, task interference is directly proportional to predicted workload[1]
  2. Combines a conflict matrix with *strategies* that actual operators use when faced with a workload-overload situation, the task management model

MRT Conflict Matrix
Channel modality pairs

[1] Wickens, 1984, 2002

3/22/11

		Channel						
		Visual	Auditory	Cognitive Spatial	Cognitive Verbal	Fine Motor	Gross Motor	Vocal
Channel	Visual	0.7 -1.0	0.4	0.6	0.4	0.5	0.2	0.2
	Auditory		0.8	0.4	0.6	0.2	0.1	0.6
	Cognitive Spatial			0.8	0.5	0.5	0.2	0.2
	Cognitive Verbal				0.8	0.2	0.1	0.6
	Fine Motor					0.8	0.6	0.5
	Gross Motor						0.4	0.4
	Vocal							1.0

MIDAS Workload Calculation

- Uses the task loads associated with a cumulative set of primitives
- Conflict is assessed should one exist
  - Demand values for each possible pair of resource channels in which neither demand is zero, are summed and added to the sum of the coefficients from the conflict matrix for the corresponding channels
  - ***Workload = K₁(Sum of demand) + K₂(sum of the conflict components)***
  - The weightings K_1 and K_2 can then be adjusted as needed to reflect differences in weighting of demand and conflict, or both kept at 1.0 as a default.
  - Stated formally, the workload equation is shown in equation:

$$W_j = K_1 \sum_{i=1}^{7} (a_{t1,1} + a_{t2,1} . a_{t3,1}) + K_2 \sum_{i=1}^{7} (cij1 + cij2 + cij3)$$

where

$Wj = ins\tan tan eous\ workload\ of\ channel\ i\ at\ time\ t,$

$j = channel$

$K_1 = channel\ cons\tan t$

$t1, t2, t3 = operator\ tasks$

$a = load\ of\ channel\ i\ to\ perform\ task\ t$

$K_2 = conflict\ cons\tan t$

$c_{i,j} = channel\ conflict$

MIDAS Workload: Baseline Output

- Workload is output for each of 7 channels

- Visualized through run-time displays or collected for post-run analyses

- Run-time output represents workload spikes, points at which the operator and hence the system is vulnerable to miss critical signals, or have increased time to complete a task given competing tasks

- Tested by comparing the workload inputs with the timeline and the task list output from the model
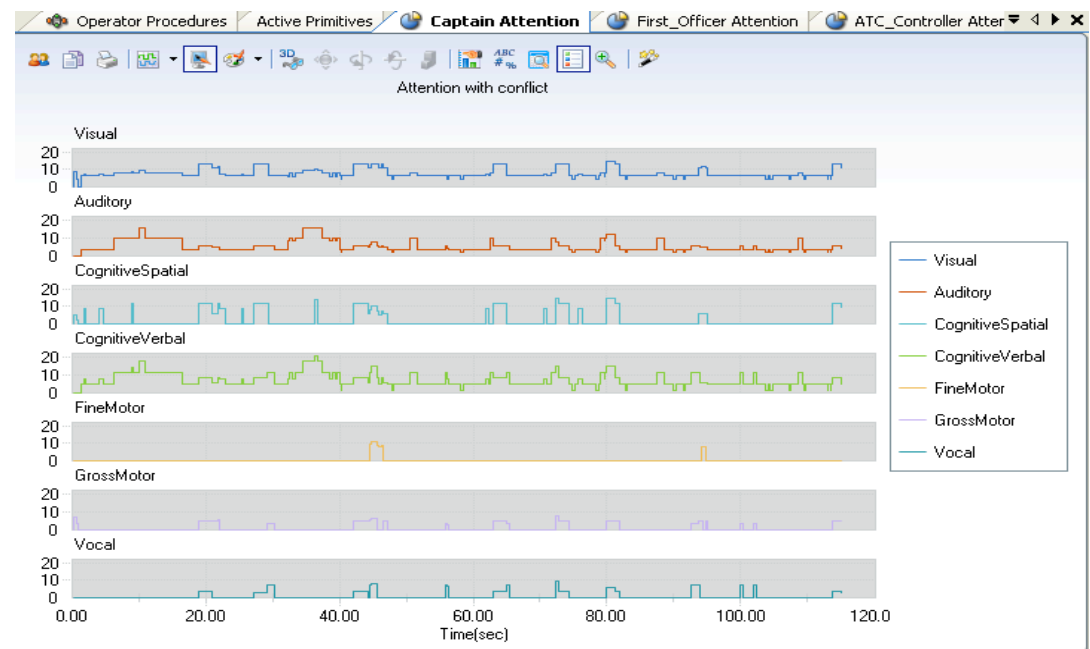
MIDAS Workload Management Model

- Reflect the *strategies* that actual operators use when faced with a "workload/overload" situation

- User input settings

  1. Workload threshold, or "red line value", for each workload channel is set by analyst

  2. Computed workload compared against channel threshold to determine operator overload (workload > threshold)

  3. primitive with the highest priority is completed

|	
Workload Management	True
Simulation To Execute	
Is Primary Simulation	True
Workload Management Settings	
Priority Weighting Duration	0
Priority Weighting Importance	4
Priority Weighting Interrupt Cost	0
Priority Weighting Urgency	0
Redline Auditory	4
Redline Cognitive Spatial	4
Redline Cognitive Verbal	7
Redline Fine Motor	4
Redline Gross Motor	4
Redline Visual	11
Redline Vocal	4

3

1
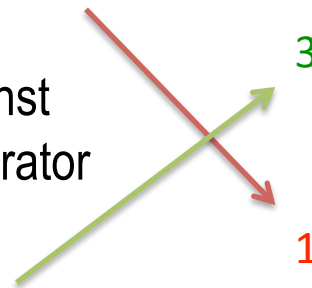
MIDAS Workload Management Model

- Primitive behavior starts, all release conditions assessed

- Priority list consulted for the next primitive that has task load that won't force an operator channel over the threshold, task is started

- Task priority/schedule[1] is driven by the (1) Importance, (2) Urgency, (3) Duration, and (4) Interrupt Cost for each operator task

- MIDAS contains functionality that manages simultaneously occurring tasks if an overload in workload is experienced

- A single task cannot cause an operator to be in overload

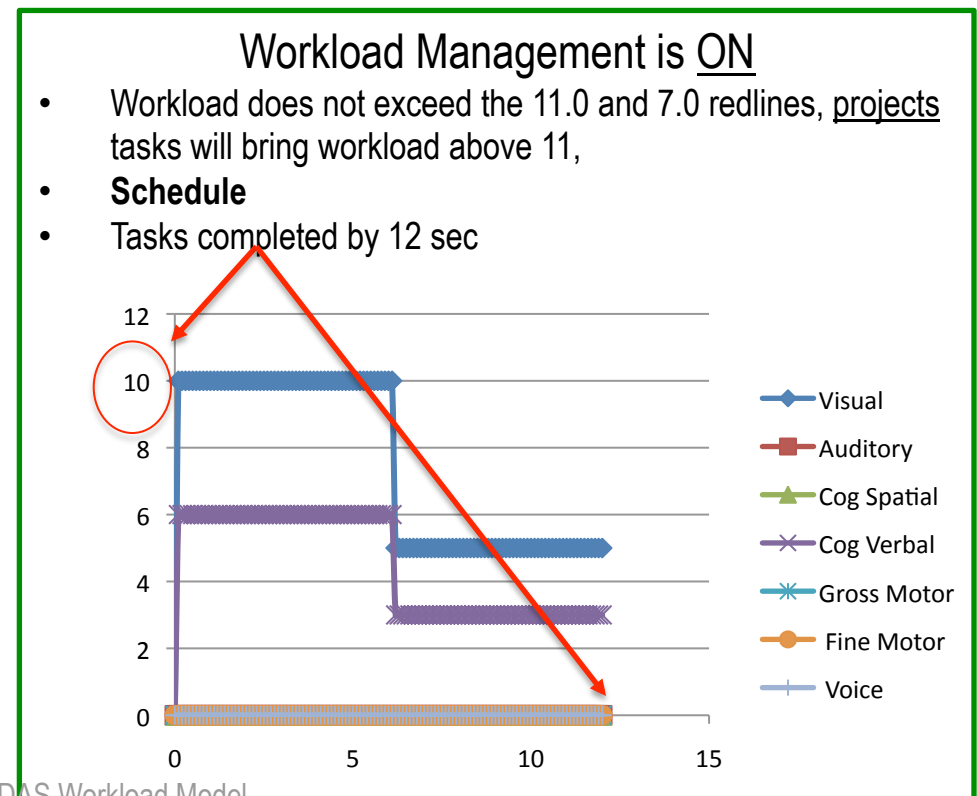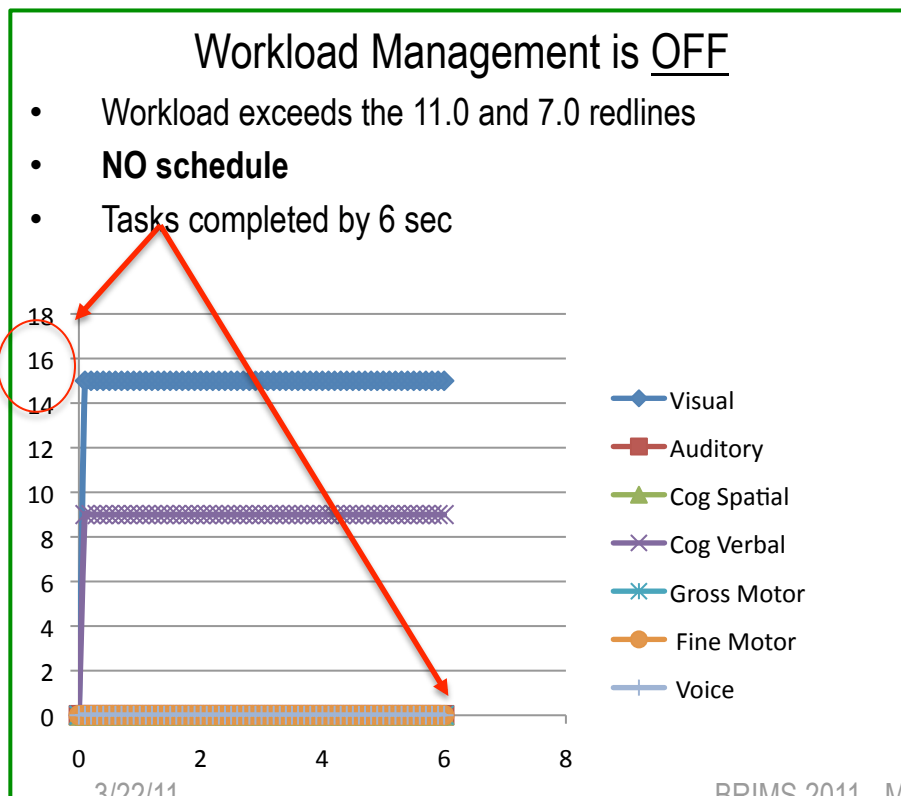[1] based on Freed, 2000; Wickens & McCarley, 2007
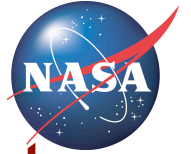
MIDAS Workload Management Model Test

- Importance
  – Each task primitive inherits importance from a high level task/context

- Urgency
  – Amount of time a task has been delayed as a proxy for urgency

- Duration
  – RelativeDuration = duration/total time of duration of delayed primitives

- Interruption Cost
  – The time cost incurred if the operator is distracted and then must reacquire the information needed to complete the task

Workload Management Verification Output

- **Importance:** set to the highest value of 4 so that task importance determines the priority of the next primitive

- **Redline Visual:** 11 allows a max of 2 simultaneous User_Read primitives

- **Redline Cognitive Verbal:** 7 allows a max of 2 User_Read primitives occur simultaneously

Workload Management is <u>OFF</u>

- Workload exceeds the 11.0 and 7.0 redlines
- **NO schedule**
- Tasks completed by 6 sec

Workload Management is <u>ON</u>

- Workload does not exceed the 11.0 and 7.0 redlines, <u>projects</u> tasks will bring workload above 11,
- **Schedule**
- Tasks completed by 12 sec

Verification Results Summary

- 5 tests conducted for each of importance, urgency, duration, and interrupt cost

- Used a simplified task network of the **Descent** context to clearly test the strategies

- Currently being extended to a high-fidelity model of pilot performance during approach and land

Workload as a Performance Shaping Factor in MIDAS: Challenges

- Workload validation
  - Empirical models exist, but practicalities sometimes dispute empirical findings
  - Anticipated personal future workload states
- Workload management strategies
  - Task management strategies currently do not allow an operator to shed a task and give it to a secondary operator when an overload condition occurs
  - Task delay versus task drop
- Channel specificity of workload definition
- Applicability to long-duration missions

Contact Information

Email: Brian.F.Gore@nasa.gov

Tel: 650-604-2542