

Quantifying Air Traffic Controller Mental Workload

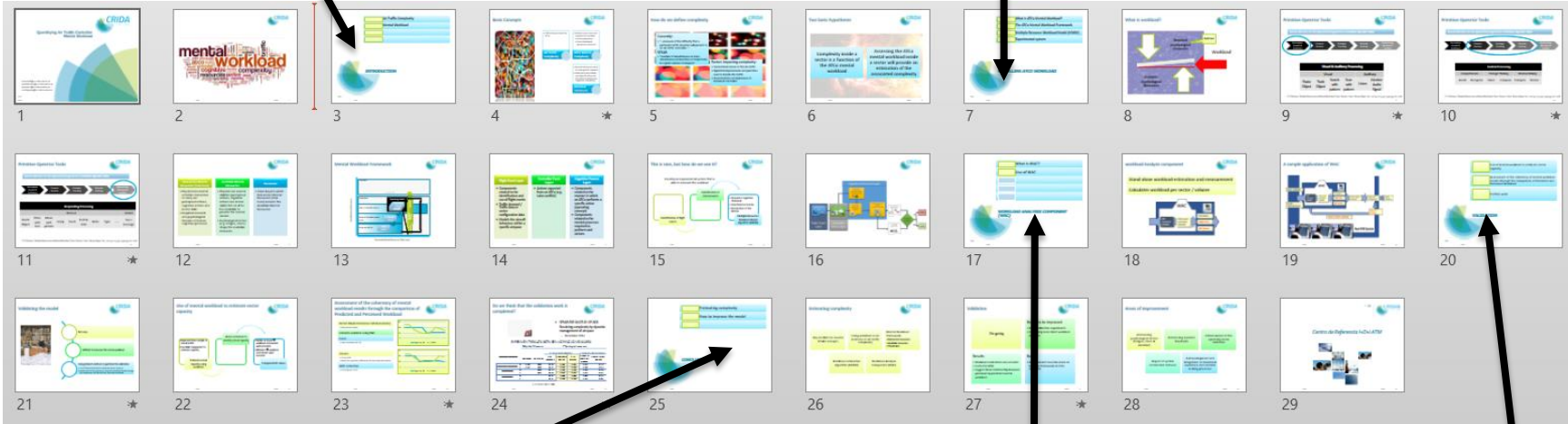
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1. Introduction

2. Modelling ATCo workload



5. Conclusions

4. Validation

3. Workload Analysis Component (WAC)

	Air Traffic Complexity
	Mental Workload



Basic Concepts



- Difficulty perceived by ATCo

Air Traffic Complexity

- Ability to perceive and respond to variables
 - Prior experience
 - Prior developed personal constructs

ATCo Mental Complexity

- Mental structures used to interpret & respond
- How each one relates, overlaps & influences the others determines cognitive complexity

Personal constructs

How do we define complexity

Currently:

- “...measure of the difficulty that a particular traffic situation will present to an air traffic controller...”

SESAR

- “number of simultaneous or near-simultaneous interactions of trajectories in a given volume of airspace”

Factors impacting complexity:

- Geometrical nature of the air traffic
- Operational procedures and practices used to handle the traffic
- Characteristics and behaviour of individual controller

Two basic hypotheses

Complexity inside a sector is a function of the ATCo mental workload

Assessing the ATCo mental workload inside a sector will provide an estimation of the associated complexity

- What is ATCo Mental Workload?
- The ATCo Mental Workload Framework
- Multiple Resource Workload Model (MWM)
- Experimental system



MODELLING ATCO WORKLOAD

Primitive Operator Tasks

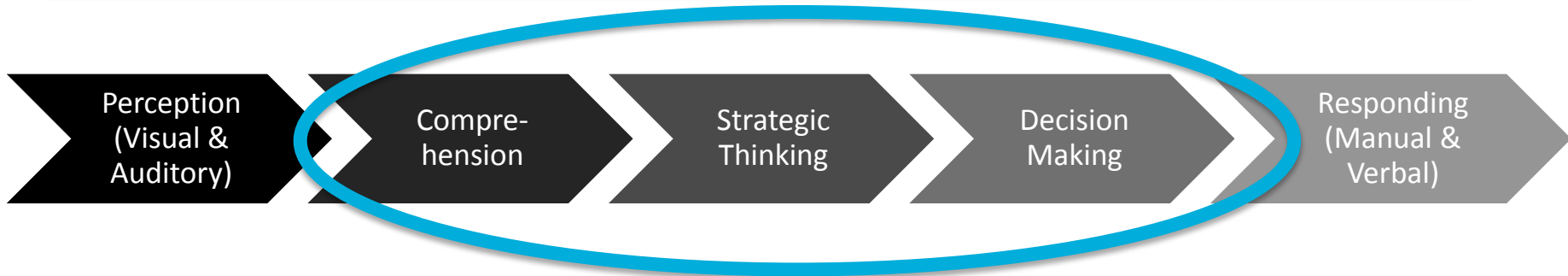
Human Behavior can be represented/segmented in **Primitive Operator Tasks**



Visual & Auditory Processing					
Visual				Auditory	
Fixate Object	Track Object	Search with pattern	Scan with pattern	Listen	Monitor Audio Signal

Primitive Operator Tasks

Human Behavior can be represented/segmented in **Primitive Operator Tasks**



Central Processing					
Comprehension		Strategic Thinking		Decision Making	
Recall	Recognise	Select	Compare	Compute	Decide

Primitive Operator Tasks



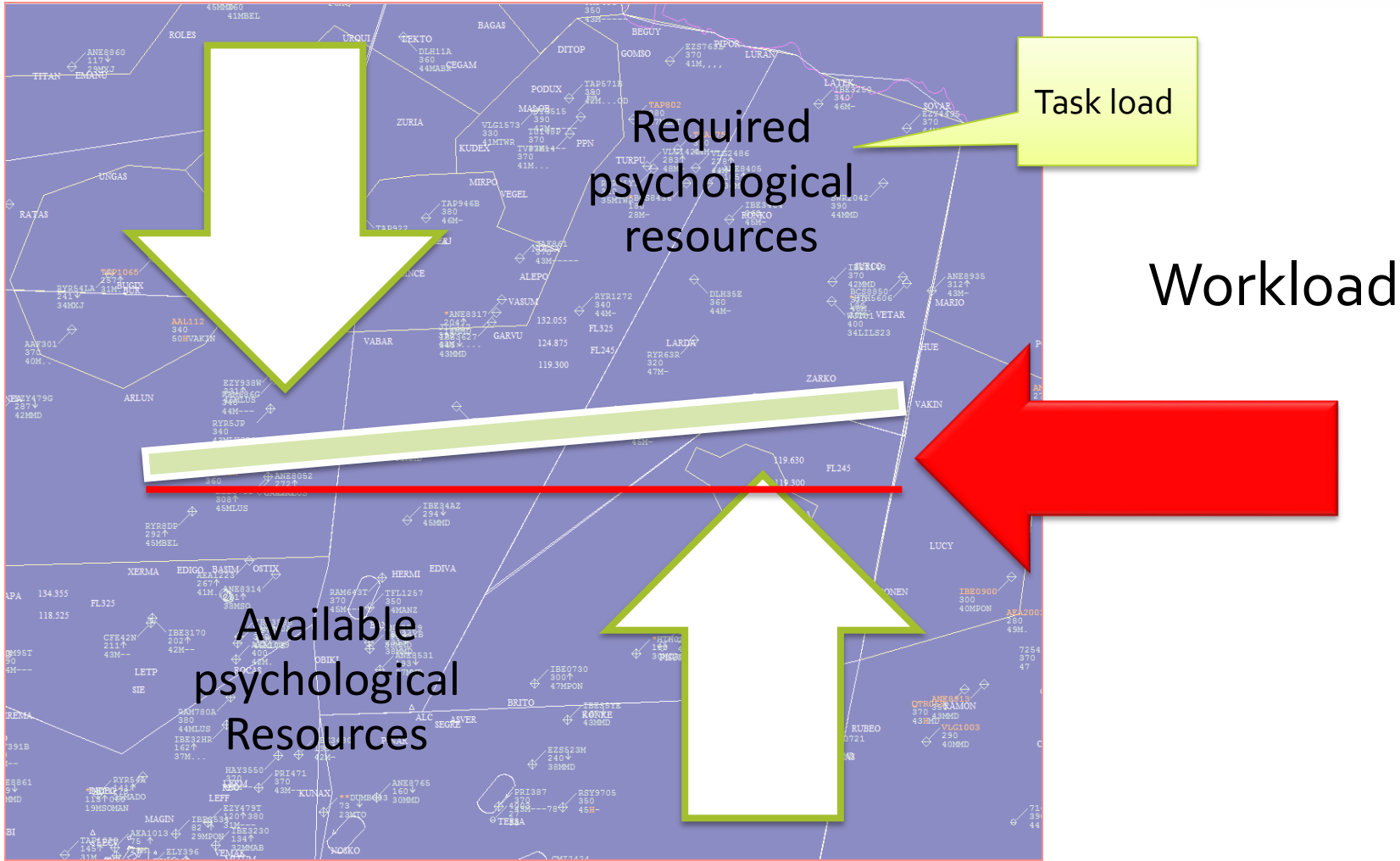
Human Behavior can be represented/segmented in **Primitive Operator Tasks**



Responding Processing									
Manual									Verbal
Reach Object	Press with foot	Move with pattern	Grasp	Touch	Push & hold	Write	Type		Say a message

C. D. Wickens, "Multiple Resources and Mental Workload," Hum. Factors J. Hum. Factors Ergon. Soc., vol. 50, no. 3, pp. 449–455, Jun. 2008.

What is workload?



Demanded Mental Resources (Task Load):

- Physical and mental activities demanded to carry out perceptual actions, cognitive actions and motor skills
- Empirical research and psychological theories of human cognitive processes

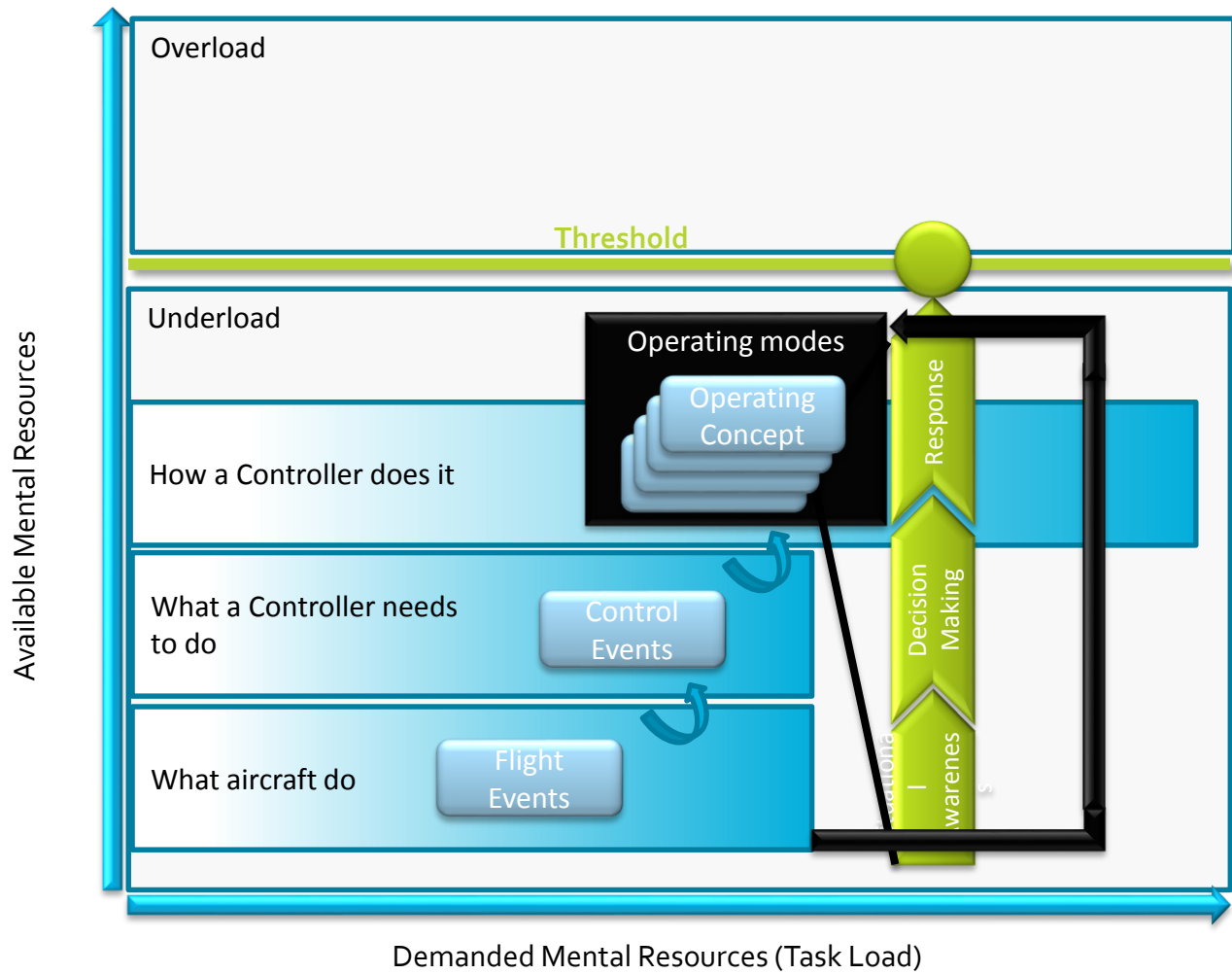
Available Mental Resources:

- Physical and mental abilities (perceptual actions, cognitive actions and motor skills) that an ATCo has available to provide the control service
- Psychological factors (e.g. fatigue, stress) shape the available resources

Threshold:

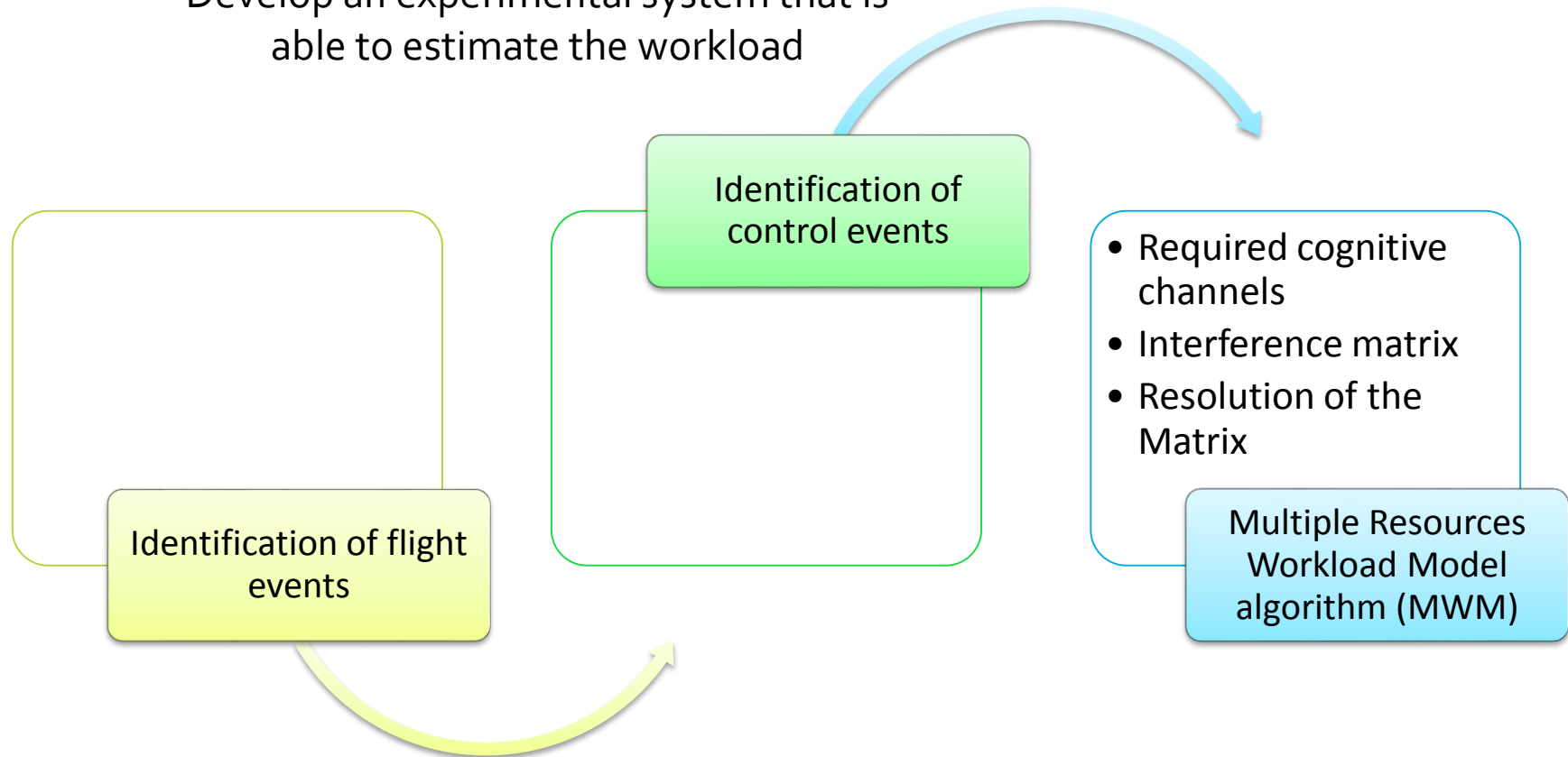
- Value beyond which Demanded Mental Resources (Task Load) exceeds the Available Mental Resources

Mental Workload Framework



This is nice, but how do we use it?

Develop an experimental system that is able to estimate the workload



Flight Event Layer:

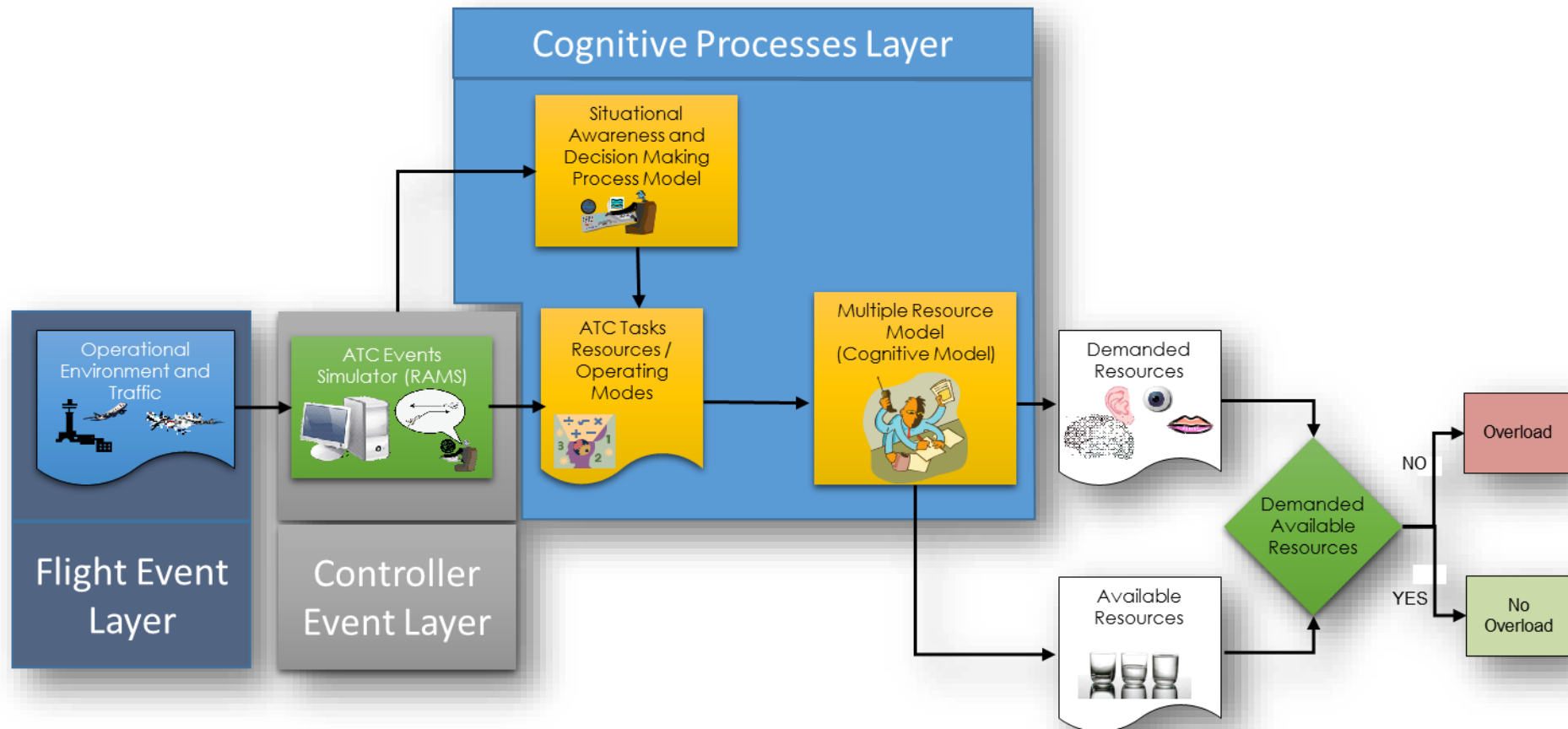
- Identification & use of flight events
- Traffic demand / Traffic data or sector configuration data
- Aircraft behaviour within a specific airspace

Controller Event Layer:

- Actions expected from an ATCo
 - e.g. solve conflict

Cognitive Process Layer:

- Manner in which an ATCo performs a specific action
 - Operating concept
- Mental processes required to perform said actions



	What is WAC?
	Use of WAC

***WORKLOAD ANALYSIS COMPONENT
(WAC)***

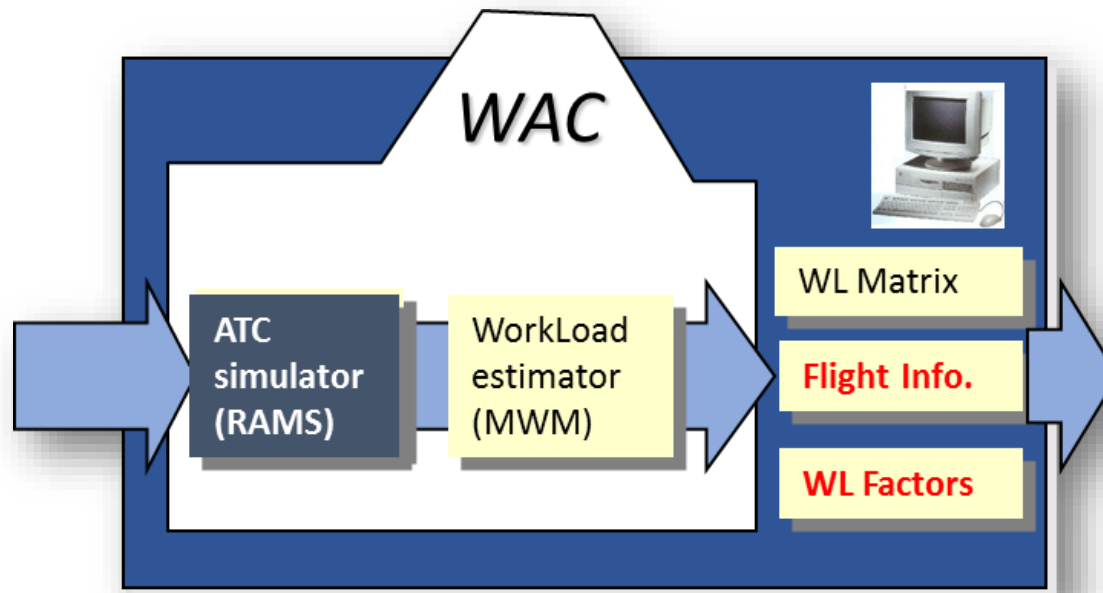


Workload Analysis component

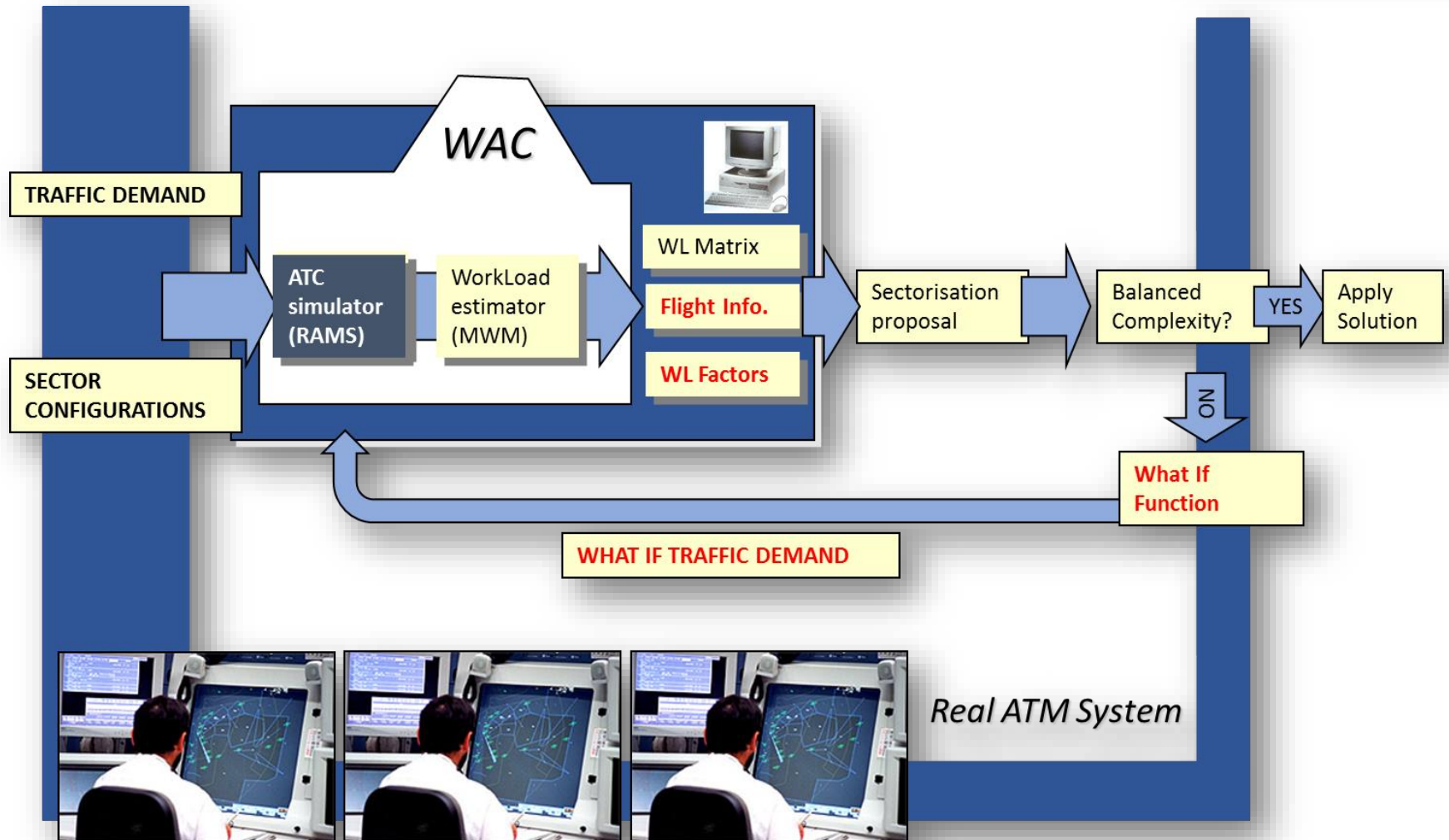


Stand alone workload estimation and measurement

Calculates workload per sector / volume



A sample application of WAC



- Use of mental workload to estimate sector capacity
- Assessment of the coherency of mental workload results through the comparison of Predicted and Perceived Workload
- Further work



Validating the model



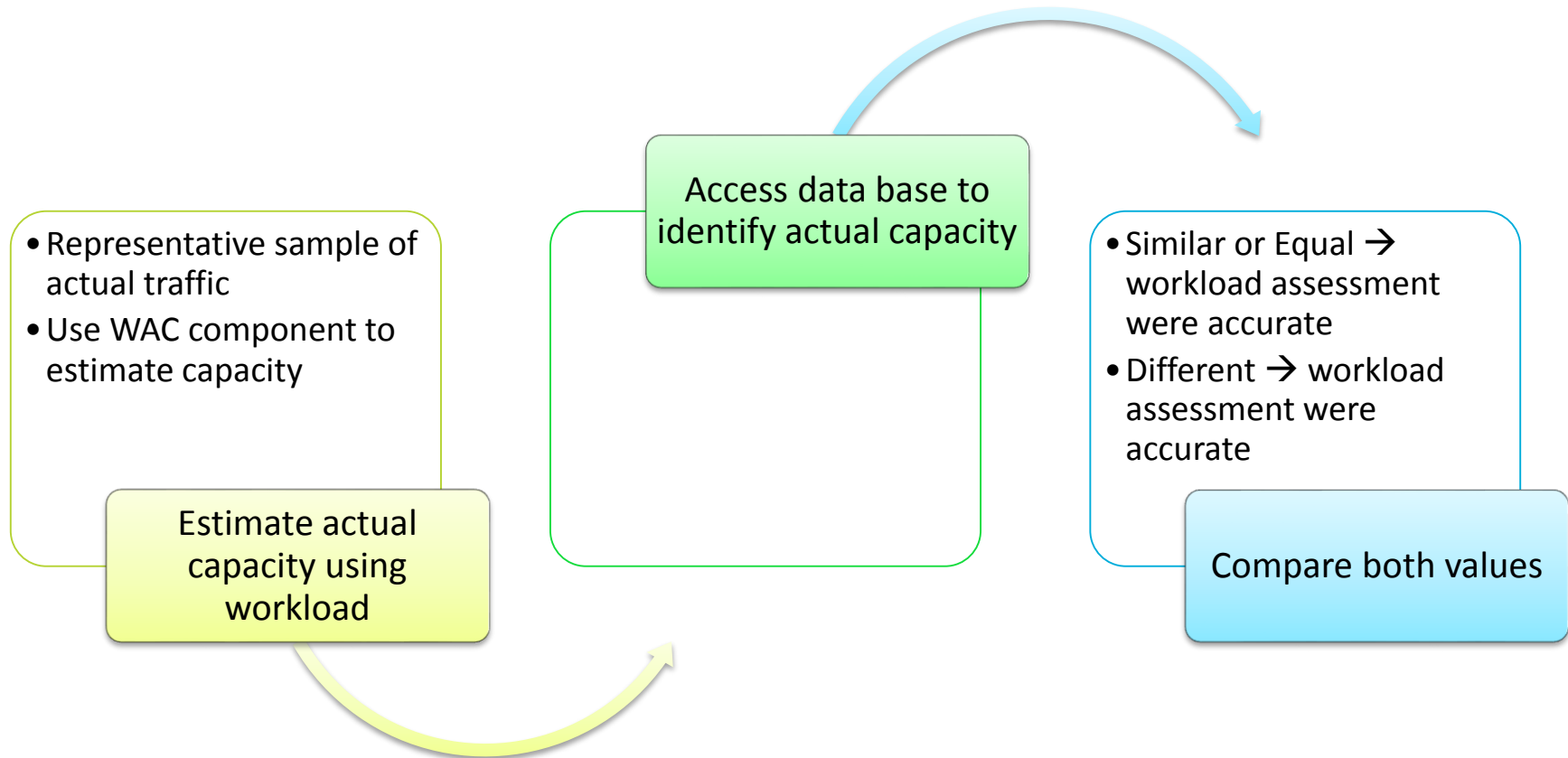
Not easy

Difficult to measure the actual workload

Using indirect methods to perform the validation

- Use of Mental Workload to Estimate Sector Capacity
- Assessment of the coherency of mental workload results through the comparison of Predicted and Perceived Workload

Use of mental workload to estimate sector capacity



Assessment of the coherency of mental workload results through the comparison of Predicted and Perceived Workload



Record ISA (Instantaneous Self Assessment)

- Normalized values

Calculate workload using WAC

Issues

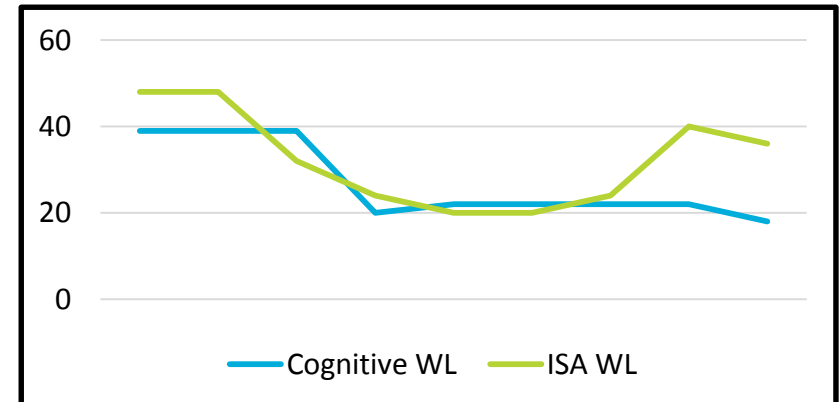
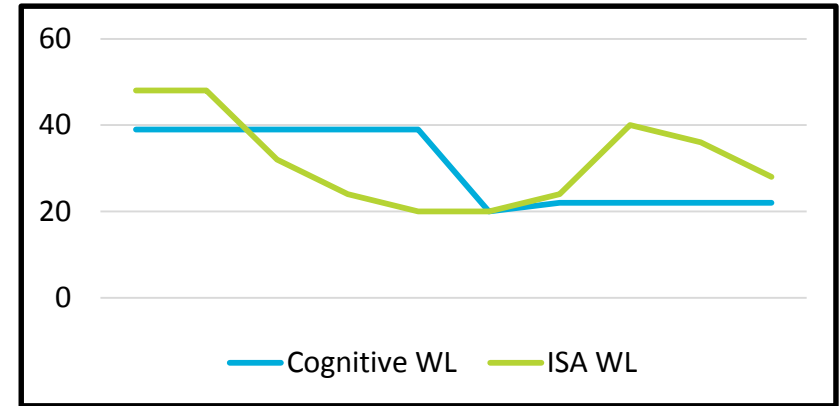
- Low correlation ($R = 0.75$, $p = 0.35$)

Causes:

- Time shift
- Need to improve calibration of non-nominal events

With correction

- Strong correlation ($R = 0.93$, $p = 0.14$)



Do we think that the validation work is completed?



NO

SESAR EXE-04.07.01-VP-003
Resolving complexity by dynamic management of airspace

- December 2014

EXPERIMENT RESULTS BETWEEN WORKLOAD MEASURES

Subjective Measures

Physiological measures

Correlation factors					Blink-related parameters		Fixation-related parameters	
		NASA-TLX	MCH score	Blink frequency	Eye closure fraction	Blink duration	Number of fixation on Regions	Fixation time on Regions
Information flow rate	R	0,908	0,908	0,904	0,927	0,741	0,910	0,774
	p	0,003	0,002	0,002	0,009	0,035	0,002	0,024
NASA-TLX	R		0,894	0,878	0,934	0,934	0,818	0,656
	p		0,003	0,004	0,001	0,001	0,013	0,077
MCH score	R			0,902	0,858	0,858	0,840	0,819
	p			0,002	0,006	0,006	0,009	0,001

Ha, Kim and Seong (2006)

- Estimating complexity
- How to improve the model

CONCLUSIONS



Estimating complexity



Key enabler for several
SESAR concepts

Using workload as an
indicator of air traffic
complexity

Mental Workload
framework:

- Demanded resources
- Available resources
- Thresholds.

Workload estimation
algorithm (MWM)

Workload Analysis
Component (WAC)

On-going

Needs to be improved

- More calibration experiments
- Identifying more direct workload methods

Results

- Workload estimations are accurate
- Useful for ATM
- Suggest relationship between perceived & predicted mental workload

But...

- Improvements must be made on both the framework and the algorithm

Areas of improvement

Introducing
psychological factors
(fatigue, stress &
emotion)

Introducing dynamic
thresholds

Enhancement of the
operating mode
definition

Impact of system
automation features

Full development and
integration of situational
awareness and decision
making processes

Centro de Referencia I+D+i ATM

