# THALES

ICAO Air Traffic Flow Management (ATFM)
Global Symposium
ATFM: together, bringing every destination closer

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Singapore, 20 to 22 November 2017

# Innovation in ATFM: the rise of Artificial Intelligence

Trevor Kistan



### Today: Big Data, Machine Learning & Predictive Analytics - 1/2

Thales CeNTAI Big Data & Analytics Laboratory & acquisitions

UNIVERSITE DIERRES MARIE CURIE

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- Custom algorithms deployed in the Thales ECOsystem ATFM product
- > Trial on 16 months of data: European domestic flights, surveillance, weather...

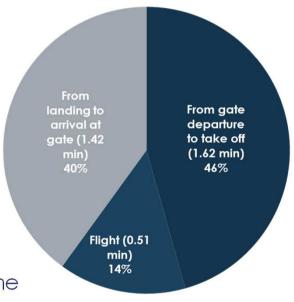
### Forecast Estimated Time of Arrival

Airlines (RMSE)	Thales (RMSE)	
12.99 min	3.25 min	

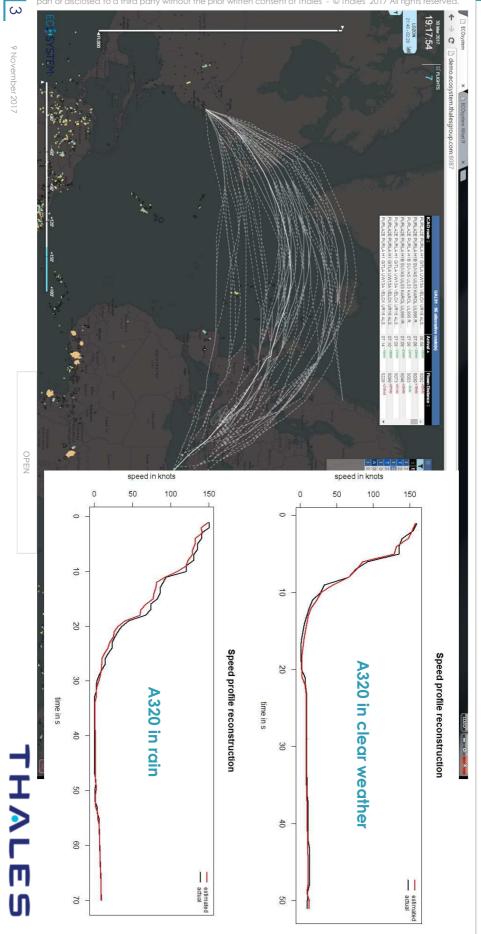
### Forecast Taxi Time

Airport	Average	σx¯	Thales (RMSE)
Paris-CDG	17.29 min	4.41 min	3.21 min
Lyon	7.86 min	0.74 min	0.52 min

- Identified main factors impacting ETA and Taxi Time
- > Superior to controls: Kernel Regression, Random Forest & Stochastic Calculus



# Today: Big Data, Machine Learning & Predictive Analytics – 2/2



# **Tomorrow: Human Machine Teaming**

### Human Machine Teaming

Machine Strengths	Human Strengths	
Precision Information acquisition Information synthesis	Creative and flexible Strategic decision making Adapt to unexpected situations	







Ψ<sub>1</sub> (Heart Rate)
Ψ<sub>2</sub> (Blood Pressure)
Ψ<sub>3</sub> (Blink Rate)
Ψ<sub>4</sub> (Blink Duration)

 $\psi'_{j,t} = f(\varphi_{i,t})$   $\psi_{j,ref}' = f(\varphi_{i,ref})$ 

 $\psi_j' = \sum_{i=1}^n \alpha_i \cdot \frac{\psi_{j,t'} - \psi_{j,ref'}}{\psi_{j,ref'}}$ 

 $\begin{array}{c} \psi_1 ' \text{ (Vigilance)} \\ \psi_2 ' \text{ (Arousal)} \\ \psi_3 ' \text{ (Workload)} \\ \hline \psi_4 ' \text{ (Stress)} \\ \vdots \\ \psi_n ' \text{ (Fatigue)} \end{array}$ 

> What are the changing roles of humans in an environment where autonomous machines operate?

# Cognitive Teaming & Adaptive HMI

- > Assess and adapt to the operator's **cognitive state** 
  - workload, fatigue, stress, attention, arousal, intent
- > Contributes towards trusted autonomy



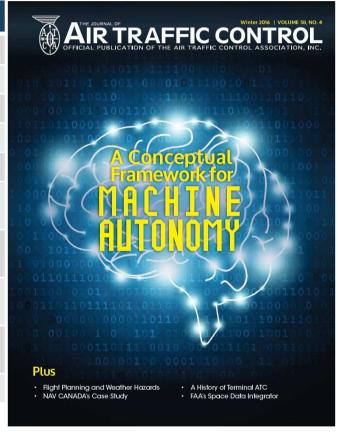
Acknowledgements :Yixiang Lim, Alessandro Gardi, Trevor Kistan, Subramanian Ramasamy, Roberto Sabatini



# Day After Tomorrow: Autonomy

or in ved.		Sheridan (aviation)
lated, in any way, in whole or in © Thales 2017 All rights reserved	1	Human does it all.
/ way, ir 17 All rig	2	Machine offers alternatives &
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anslateds - © Th	4	suggets one, &
shed, tr of Thale:	5	executes if human approves, or
apted, publi en consent	6	allows human set time to veto before executes automatically, or
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not be reproduced, modified, adapted, published, franslated, in any way, in whole or in a third party without the prior written consent of Thales - © Thales 2017 All rights reserved	8	informs human after execution if the human asks it, or
nay not be re to a third po	9	informs human after execution if it decides to.
ment may isclosed to	10	Machine acts autonomously.

Adapted from: Sheridan, T. B. Telerobotics, Automation, and Human Supervisory Control. The MIT Press. 1992.



<b>SAE J3016</b> (	(automobil	es)
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0	No Automation
1	Driver Assistance
2	Partial Automation
3	Conditional Automation
4	High Automation
5	Full Automation

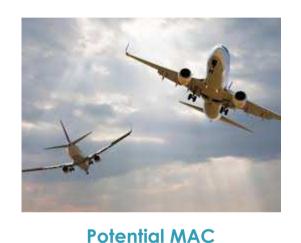
Reference: SAE J3016: Taxonomy & Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems.

"The post-GDP traffic build-up is an **emergent phenomenon** arising from the interaction of traffic flow practices with airlines' business rules."

Reference: Liviu Nedelescu, "A Conceptual Framework for Machine Autonomy", ATCA Journal of ATC, Winter 2016, Vol. 58, No. 4

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# Case Study: Future of the Traffic Collision Avoidance System (TCAS)





- Airborne Collision Avoidance System (ACAS X) is a Neural Network
  - > No "if-then-else" rules !!!
  - Trained on millions of simulated encounters & 180 000 real-life potential collisions
  - > BUT Trust: Verification, Certification and Explanatory Power

Reference: "Smarter Collision Avoidance", Aerospace America, June 2017.



output layer

6

OPEN

# **XAI: Explainable Artificial Intelligence**

**EU General Data Protection Regulation,** Article 22

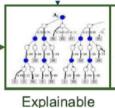






New Learning

**Process** 



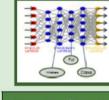
Model

It has fur, whiskers, and claws. It has this feature:

This is a cat:

Explanation Interface \*

- · I understand why
- · I understand why not
- · I know when you'll succeed
- · I know when you'll fail
- · I know when to trust you
- · I know why you erred



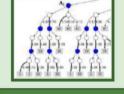
### **Deep Explanation**

**Learning Semantic** Associations

H. Sawhney (SRI Sarnoff)

Learning to Generate **Explanations** 

T. Darrell, P. Abeel (UCB)



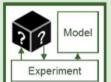
### Interpretable Models

Stochastic And-Or-Graphs (AOG)

Song-Chun Zhu (UCLA)

**Bayesian Program** Learning

J. Tenenbaum (MIT)



### **Model Induction**

Local Interpretable Model-agnostic Explanations (LIME)

C. Guestrin (UW)

**Bayesian Rule Lists** C. Rudin (MIT)



### HCI

Prototype **Explanation Interface** T. Kulesza (OSU/MSR)

UX Design, Language

Dialog, Visualization **ENGINEERING PRACTICE** 



### **Psychology**

Principles of Explanatory Machine Learning

M. Burnett (OSU)

**Psychological Theories** of Explanation

T. Lombrozo (UCB)



Reference: David Gunning, Explainable Artificial Intelligence (XAI), DARPA/I20, https://www.cc.gatech.edu/~alanwags/DLAI2016/(Gunning)%20IJCAI-16%20DLAI%20WS.pdf

OPEN



# Potential applications of Automation & Al in ATFM

### Automation can be applied at 4 stages:

Reference: Parasuraman, R., Sheridan, T. B., & Wickens, C. D. (2000). A model for types and levels of human interaction with automation. IEEE Transactions on systems, man, and cybernetics, 30(3), 286 - 297.

Data Acquisition	Data Interpretation	Decision Selection	Action Selection
Smart Sensors: Space- based ADS-B, 4-D weather cube, biometrics	Identification & Prediction: major traffic flows, workload, congestion, flight delays, arrival time	Decision Support: scheduling, multi-agent flow control, sector planning, airport configuration	Pre-tactical Conflict Detection and Al-based Resolution: hotspots, multiple flights or flows, weather
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