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PROJECT ATCOSIMA: PRELIMINARY RESULTS AND ANALYSIS OF REAL-TIME ATC AND FLIGHT COCKPIT SIMULATIONS

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Introduction

✓European Union's Single European Sky (SES) initiative aims to create an integrated Pan-European Air Traffic Management (ATM)
- ✓ according to air traffic flows rather than national boundaries
- ✓ in order to handle the ever-increasing air traffic safely, efficiently and economically.

✓This integration requires adaptation of a common:
- ✓ legislative framework
- ✓ technological infrastructure
- ✓ also standardized and enhanced air traffic controller (ATCo) training

✓EU and EUROCONTROL documents state a set of general performance objectives for the training
- ✓ neither they define any standard metrics and scoring for the assessment process
- ✓ nor they include SESAR's targets regarding efficiency and economics of traffic flow.

✓ATCOSIMA (Development of Common ATC Simulation Training Assessment Criteria Based on Future Pan European Single-Sky Targets) project aims to address this issue and proposes an innovative approach to measure the performance of ATCo trainees in radar approach simulations based on integrated ATC radar and cockpit simulations.

✓ This study presents the preliminary results and analysis of real-time ATC radar and integrated ATC-flight cockpit simulations as a baseline study to develop the new assessment criteria for ATCo radar simulation training.

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Research Methodology

- ✓ Simulation experiments have been done
  - ✓ for the project's first and second stages
  - ✓ involve with the baseline analysis to evaluate performance of ATC trainees using current assessment criteria
- ✓The first stage consists of ATC radar simulations done in ESTU and ZFOT.
  - ✓ 19 ATCo trainees (14 from ZFOT and 5 from ESTU)
  - ✓ Under the supervision of 3 ATC instructors (2 from ZFOT and 1 from ESTU)
  - ✓ The trainees were selected among the enrolled students of ESTU or ZFOT
  - ✓ Required to pass radar approach control course before.
  - ✓ Each student run 10 exercises with increasing level of difficulty based on the traffic complexity.
  - ✓ The experiments were not interrupted
  - ✓ No guidance by the instructors except individual or group briefings and debriefings prior to or after the simulations.
- ✓ The second stage includes the integrated ATC radar and flight cockpit simulations at TUBS
  - ✓ 10 trainees (5 from ZFOT and 5 from ESTU)
  - ✓ A selected exercise (EXE009) were run for each trainee using the simulation setup.

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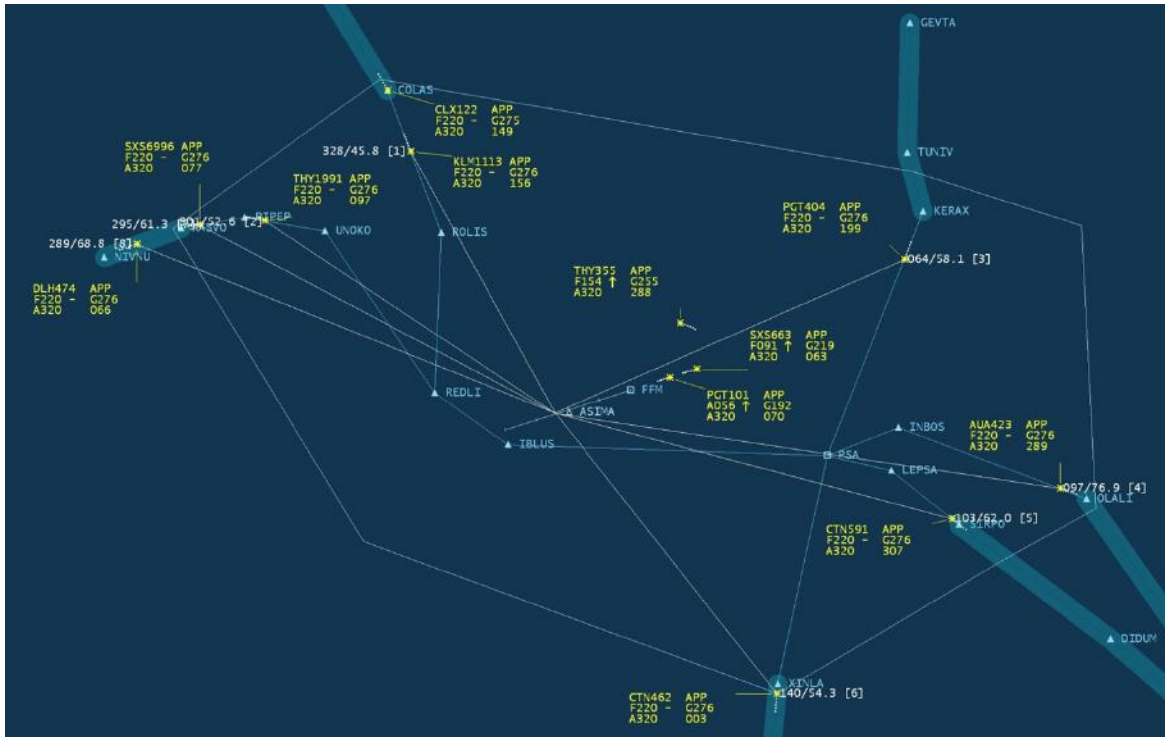
Airspace and Exercise Scenario

✓A new airspace model was developed to be used in the generic exercises for simulations
- ✓ based on Frankfurt TMA different from the airspaces used in ATC simulation courses at ESTU and ZFOT
- ✓ yet easy to adapt for trainees
- ✓ large size and convex boundaries
- ✓ relatively longer time window for planning and execution of tasks during the exercises.
- ✓ the difficulty of the exercises is **due to the traffic density and mixture** rather than **the airspace structure**.

✓The test exercise (EXE009) has the following features:
- ✓ **9 arriving** and **3 departing** aircraft within the TMA
- ✓ All these arriving aircraft have **similar estimated flyover times** at REDLI fix near ILS course.
- ✓ 4 arriving aircraft to be sequenced with respect to PSA fix.
- ✓ Requires effective and timely use of **vectoring, airspeed adjustments** and **flight level change.**
- ✓ **A single aircraft type** (i.e. Airbus A320) has been simulated in all exercises.
- ✓ Aircraft performance data used in simulation are based on Base of Aircraft (BADA)



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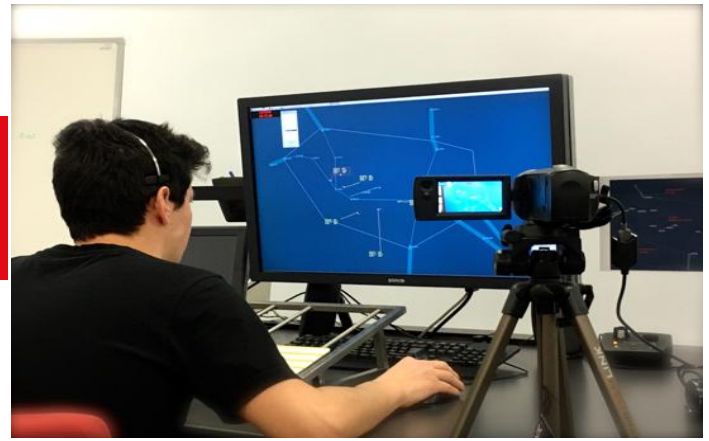
ATC Radar Simulations



- ✓Simulation experiments have been conducted in two parallel groups at ESTU and ZFOT between February-April 2018.
- ✓Both partners use MicroNav BEST ATC Radar Simulators
- ✓The systems consist of ATCo and pseudo-pilot controller workstations.
- ✓Trainees used printed flight strips to note all clearances and instructions given to aircraft during the simulations.
- ✓The following data sets have been collected during the exercises:
  - ✓ Exercise replay files and exercises logs
  - ✓ Video screen capture files from ATCo workstation
  - ✓ Replay files were used by instructors to assess the trainees' performance based on ATCO assessment validation criteria
  - ✓ Flight trajectory metrics (i.e. arrival sequence, distance flown by each aircraft, exercise duration and aircraft spacing on the ILS course
- ✓the number of instructions (i.e. flight level, heading and speed) given by trainees in each exercise and the number of tasks (i.e. distance and heading measurements and relocating aircraft labels) were detected.

BEST experiments video

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Integrated ATC Radar-Flight Cockpit Simulations

- ✓Conducted at the Institute of Flight Guidance of TUBS in **June 19-22, 2018** with the participation of teams from ESTU, ZFOT and TUBS.
- ✓The test bed used in simulations consists of the flight deck and ATC radar control simulators.
- ✓The flight cockpit simulator is a fixed based simulator containing **a full-replica mock-up of an Airbus A320** cockpit.
- ✓ATC Radar Simulator provides a generic aircraft simulation environment for air traffic controller trainees with its two full functional air traffic controller workstations
- ✓A set of modifications had been done in the system modules such as distance and bearing measurement tool, aircraft prediction line and adoption of color themes compatible with BEST Radar Simulator GUI
- ✓The following data sets have been collected:
  - ✓ Flight cockpit simulator flight data recorder (FDR) data
  - ✓ Cockpit video recordings for pilot actions
  - ✓ ATC simulator log files
  - ✓ Video screen capture files from ATCo workstation
  - ✓ NASA task load index questionnaire data

ATC-Cocpit simulations video

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Results and Analysis: ATC Radar Simulations

- ✓In the first step, the following data were analyzed for **all 19 trainees** participated in ATC Radar Simulations (the first data set):
  - ✓ **Flight and traffic performance metrics** (i.*e. spacing between aircraft, flight time and distance flown*),
  - ✓ **ATCo instructions** (i.*e. flight level, heading and airspeed*)
  - ✓ **Assessment scores**
- ✓Average aircraft spacing on the ILS course:
  - ✓ Although 5 NM separation minima is required between aircraft pairs, the mean spacing provided by trainees is about 8 NM per pair.
  - ✓ This result indicates vectoring instructions ensures safety constraint yet they are not efficient in terms of spacing arrival sequence along the ILS course.
- ✓Exercise duration:
  - ✓ The difference between the minimum and maximum exercise durations is six minutes which indicates large variations between trainees in handling arrival sequence.
- ✓Total distance flown indicates the sum of the distances of arrival:
  - ✓ This value directly affects airborne total delays and fuel consumption; therefore, it is an important indicator of efficiency.
- ✓Number of instructions provides an important indicator to understand their approach to handling the traffic.
  - ✓ These values also indicate large variations among the trainees.

Descriptive statistics (the first data set)

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Average aircraft spacing on the ILS course	19	7.1	9.2	8.01	0.57
Exercise duration	19	33.5	39.5	37.27	1.78
Total distance flown	19	78.3	96.5	84.59	5.34
Total flight level instructions	19	26	52	36.00	6.77
Total heading instructions	19	24	52	32.21	6.79
Total speed instructions	19	5	35	25.47	9.99
Assessment score	19	65	100	91.68	9.11

Normality tests (the first data set)

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Aircraft spacing on the ILS course (NM)	.097	19	.200*	.975	19	.877
Exercise duration (min)	.151	19	.200*	.937	19	.229
Total distance flown (NM)	.210	19	.027	.897	19	.043
Total flight level instructions	.125	19	.200*	.934	19	.206
Total heading instructions	.302	19	.000	.720	19	.000
Total speed instructions	.231	19	.009	.808	19	.002
Assessment score	.303	19	.000	.692	19	.000

*. This is a lower bound of the true significance. a. Lilliefors Significance Correction

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Results and Analysis: ATC Radar Simulations

- ✓The next step focuses on the ATC radar simulations results **10 trainees** also participated in **the integrated ATC and flight cockpit simulations** at TUBS (the second data set).
- ✓Their video screen capture files were analyzed through visual analysis in order to determine what kind of ATC tasks they performed during the same exercise.
- ✓The descriptive statistics show that individual variations are relatively less in efficiency metrics, ATCo instructions and assessment scores.
- ✓Besides these indicators, number of ATC tasks (i.e. heading and distance measurements and relocating aircraft labels) performed by trainees are also presented in
- ✓The results indicate that tasks performed by trainees are remarkably different during the exercise.

Descriptive statistics (the second data set)

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Average aircraft spacing on the ILS course	10	7.06	8.33	7.78	.38
Average exercise duration	10	33.53	38.37	36.10	1.49
Average of total distance flown	10	78.30	96.53	86.65	6.48
Total flight level instructions	10	32	52	40.40	5.91
Total heading instructions	10	24	52	34	9.10
Total speed instructions	10	5	35	20.30	11.36
Distance measurement between aircraft	10	5	38	14.60	9.05
Distance measurement between aircraft and ILS course	10	0	22	11.60	6.38
Heading measurement	10	4	52	22.30	18.76
Relocating aircraft labels	10	33	99	60.60	24.68
Assessment score	10	70,00	100,00	92.00	8.35

Normality tests (the second data set)

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Average aircraft spacing on the ILS course (NM)	.200	10	.200*	.930	10	.449
Exercise duration(min)	.166	10	.200*	.959	10	.773
Total distance flown (NM)	.151	10	.200*	.928	10	.429
Total flight level instructions	.260	10	.055	.881	10	.133
Total heading instructions	.244	10	.094	.847	10	.053
Total speed instructions	.218	10	.197	.891	10	.173
Distance measurement between aircraft	.326	10	.003	.741	10	.003
Distance measurement between aircraft and ILS course	.101	10	.200*	.988	10	.994
Heading measurement	.261	10	.052	.852	10	.062
Relocating aircraft labels	.236	10	.120	.871	10	.102
Assessment score	.300	10	.011	.732	10	.002

*. This is a lower bound of the true significance. a. Lilliefors Significance Correction

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Results and Analysis: ATC Radar Simulations Correlation Analysis (the first data set)

Variable Pairs	Sig.	Pearson /Spearman Correlation Coefficient (r)
Average aircraft spacing on the ILS course (NM)* Exercise duration (min)	.004	.630**
Exercise duration (min) * Total flight level instructions	.002	-.670**
Exercise duration (min) * Total speed instructions	.021	.524*
Total distance flown (NM) * Assessment score	.032	-.494*
Total distance flown (NM) * Total speed instructions	.000	-.759**
Total flight level instructions * Total speed instructions	.001	-.711
*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). All other comparisons were non-significant.		

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Results and Analysis: ATC Radar Simulations Correlation Analysis (the second data set)

Variable Pairs	Sig.	Pearson correlation (r) /Spearman's rho
Average exercise duration * Total speed instructions	.038	.660*
Average exercise duration * Heading measurement	.007	-.790**
Average of total distance flown * Total flight level instructions	.029	.685*
Total flight level instructions * Total speed instructions	.002	-.853**
Average of total distance flown * Heading measurement	.001	.852**
Total flight level instructions * Total heading instructions	.004	820**
Total flight level instructions * Total speed instructions	.036	-.665*
Total flight level instructions * Heading measurement	.004	.811**
Total heading instructions * Heading measurement	.003	.826**
Total speed instructions * Heading measurement	.001	-868**

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).
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Results and Analysis:
Integrated ATC Radar and Flight Cockpit Simulations

✓The perceived mental, physical, and temporal demand and performance, frustration and effort of the A320 cockpit flight simulator pilot and air traffic controller trainees were measured using NASA task load index (TLX)

✓the correlation coefficients between the workload perceptions of the pilots and the controllers and the flight time, distance flown and fuel consumption of the A320 flight cockpit simulator were also examined.

Descriptive statistics of NASA-TLX scores and flight data of the A320 cockpit simulator

Category	Variable	N	Mean	Std. Deviation
ATC Trainee's Task Load Scores	Mental Demand	12	60.41	3.75
	Physical Demand	12	31.25	19.20
	Temporal Demand	12	57.91	23.40
	Performance	12	39.17	19.98
	Effort	12	68.33	15.27
	Frustration	12	43.75	21.76
	Overall	12	57.05	11.75
Pilot's Task Load Scores	Mental Demand	12	57.50	7.83
	Physical Demand	12	32.08	5.42
	Temporal Demand	12	25.00	5.22
	Performance	12	25.00	8.85
	Effort	12	66.25	8.83
	Frustration	12	22.50	11.38
	Overall	12	46.28	6.57
Flight Cockpit FDR Data	Flight Duration (min)	10	30.50	3.75
	Distance Flown (NM)	10	138.61	8.20
	Fuel Consumption (kg)	10	784.13	75.80

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Results and Analysis:
Integrated ATC Radar and Flight Cockpit Simulations

T-test results of the task load scores of ATC trainees and the pilot

Variable	Task	N	Mean	Std. Deviation	df	t	p
Mental Demand	Pilot	12	57.50	7.83	22	-.687	.501
	Trainee	12	60.41	3.75			
Physical Demand	Pilot	12	32.08	5.42	22	.145	887
	Trainee	12	31.25	19.20			
Temporal Demand	Pilot	12	25.00	5.22	22	-4.756	.000
	Trainee	12	57.91	23.40			
Performance	Pilot	12	25.00	8.85	22	-2.259	.039
	Trainee	12	39.17	19.98			
Effort	Pilot	12	66.25	8.83	22	-.409	.686
	Trainee	12	68.33	15.27			
Frustration	Pilot	12	22.50	11.38	22	-2.998	.007
	Trainee	12	43.75	21.76			
Overall	Pilot	12	46.28	6.57	22	-2.772	.011
	Trainee	12	57.05	11.75			

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Results and Analysis:
Integrated ATC Radar and Flight Cockpit Simulations

Correlation analysis results for the pilot

Variable Pairs	Sig.	Pearson correlation (r)
Flight duration (min)* fuel consumption (kg)	.021	.713*
Flight duration (min)* overall	.014	.742*
Flight distance* fuel consumption (kg)	.026	.695*
Flight distance*Physical demand	.019	.720*
Fuel consumption* Physical demand	.003	.831
Mental demand*Performance	.000	.851**
Mental demand*effort	.036	.608*
Mental demand*overall	.000	.901**
Performance*effort	.027	.634*
Performance*frustration	.036	.609*
Performance*overall	.001	.812**
Effort*frustration	.009	.713**
Effort*overall	.003	.780**
Frustration*overall	.036	.607*
*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). All other comparisons were non-significant.		

Correlation analysis results for ATC trainees

Pairs	Sig.	Pearson correlation (r)
Flight duration (min)* fuel consumption (kg)	.021	.713*
Flight duration (min)* physical demand	.008	-.776**
Flight distance* fuel consumption (kg)	.026	.695*
Mental demand*temporal demand	.000	.857**
Mental demand*overall	.037	.605*
Temporal demand*effort	.008	.721**
Temporal demand*overall	.000	.860**
Performance*frustration	.015	.682*
Effort*overall	.003	.775**
*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). All other comparisons were non-significant.		

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Conclusion and Discussions

✓Preliminary results of ATC radar simulation show a **significant difference among the trainees' approaches** to handle arriving traffic in terms of the number of instructions.

✓Observed moderate **positive relationship** between **exercise duration and average aircraft spacing** on the ILS course indicates that effective use of radar vectoring techniques can increase service throughput.

✓ Therefore, **arrival separation management on the ILS course** can be one of the possible developments in the new assessment criteria.

✓ Similarly, **the number of speed instructions** have a **negative impact on exercise duration** and therefore on the throughput because most of the speed adjustments were observed as speed reduction.

✓Trainees can be encouraged to use alternative techniques depending on the traffic complexity but still more extensive analyses are required over the larger set of data to determine efficient combination of different instructions.

✓Task load analysis also showed that there is **strong relationship** between **flight duration-fuel consumption** and **moderate relationship** between **flight distance-fuel consumption.**

✓ Therefore, ATCo instructions reducing **flight duration should be studied more thoroughly** in order to **increase flight efficiency**.

✓Task load analysis also indicated a **strong negative relationship** between **flight duration and physical demand** of ATC controller tasks.

✓This can be interpreted as **effective traffic management** requires **more heading and distance measurement actions** to estimate efficient arrival sequencing and conflict resolution.

✓For the future work similar analyses will be done for all ATC radar exercises and traffic complexity metrics such as number of aircraft, arrival-departure mix, conflict encounter geometries and time separation between departing aircraft will be considered.

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