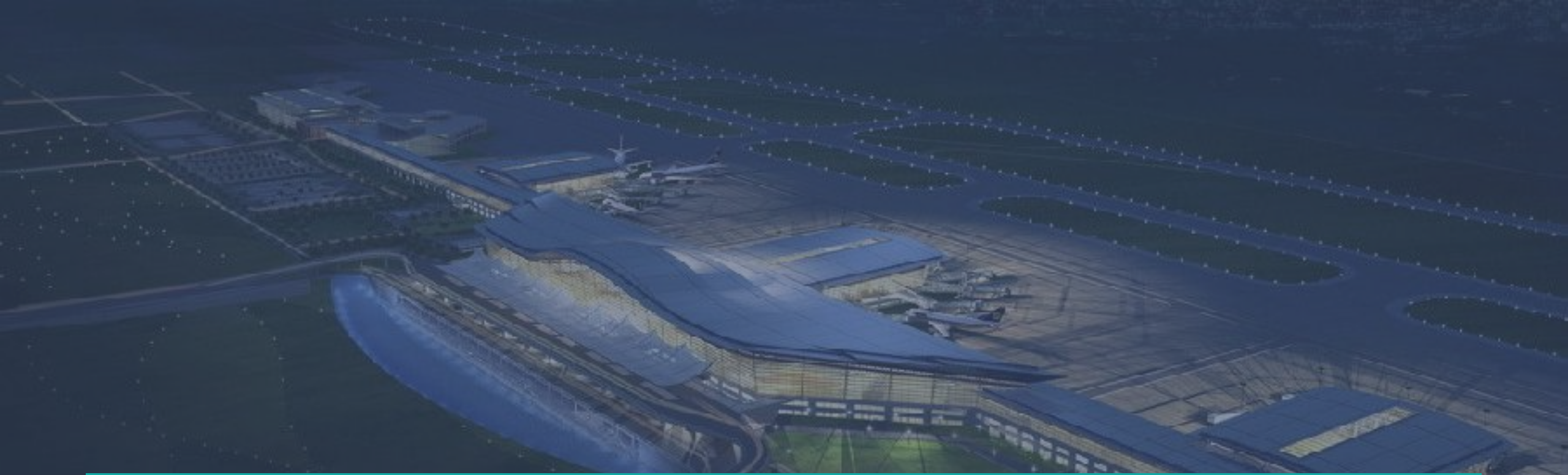
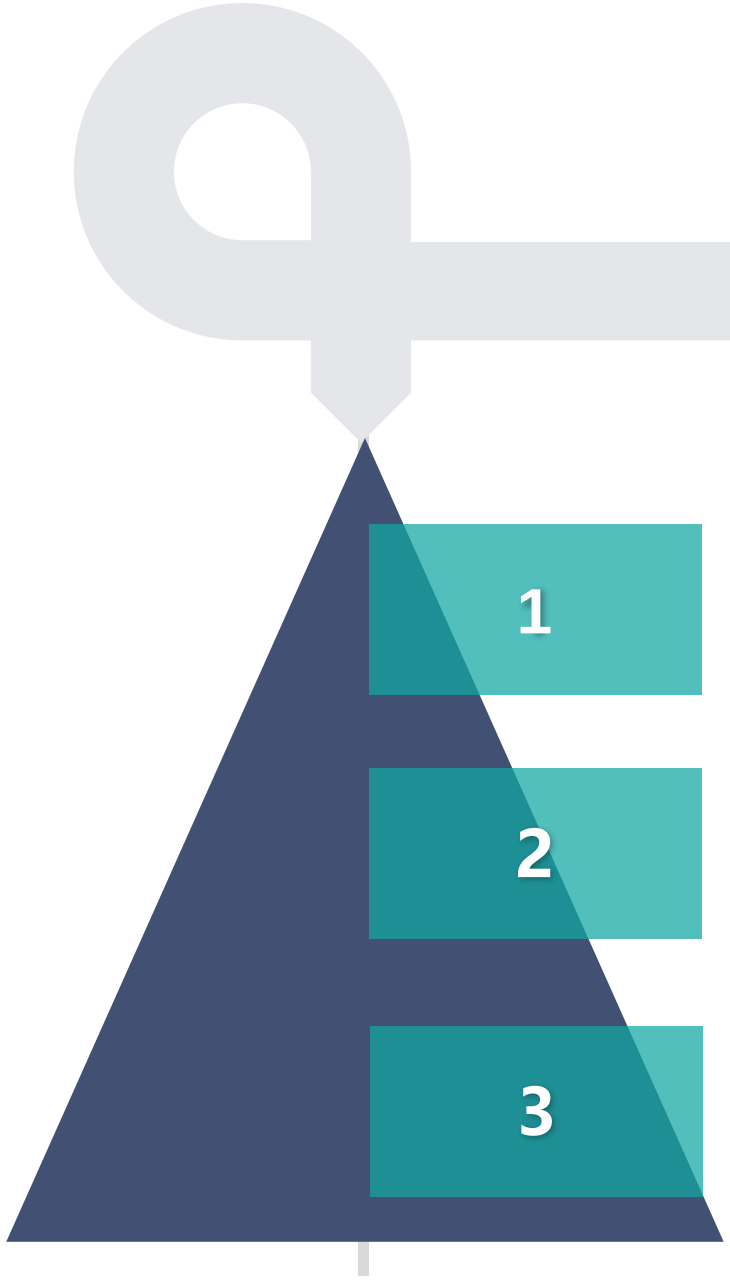


Multiple Evaluation for the Flight Procedure Design and Operation

Junfeng ZHANG

Outline



1. Evaluation for Procedure Design
2. Evaluation for Procedure Validation
3. Evaluation for Procedure Operation

How to illustrate the evaluation work about

Flight Procedure Design, Validation, and operation ?

Aim & Focus

- Why should we conduct evaluation
- What is the focus of the evaluation

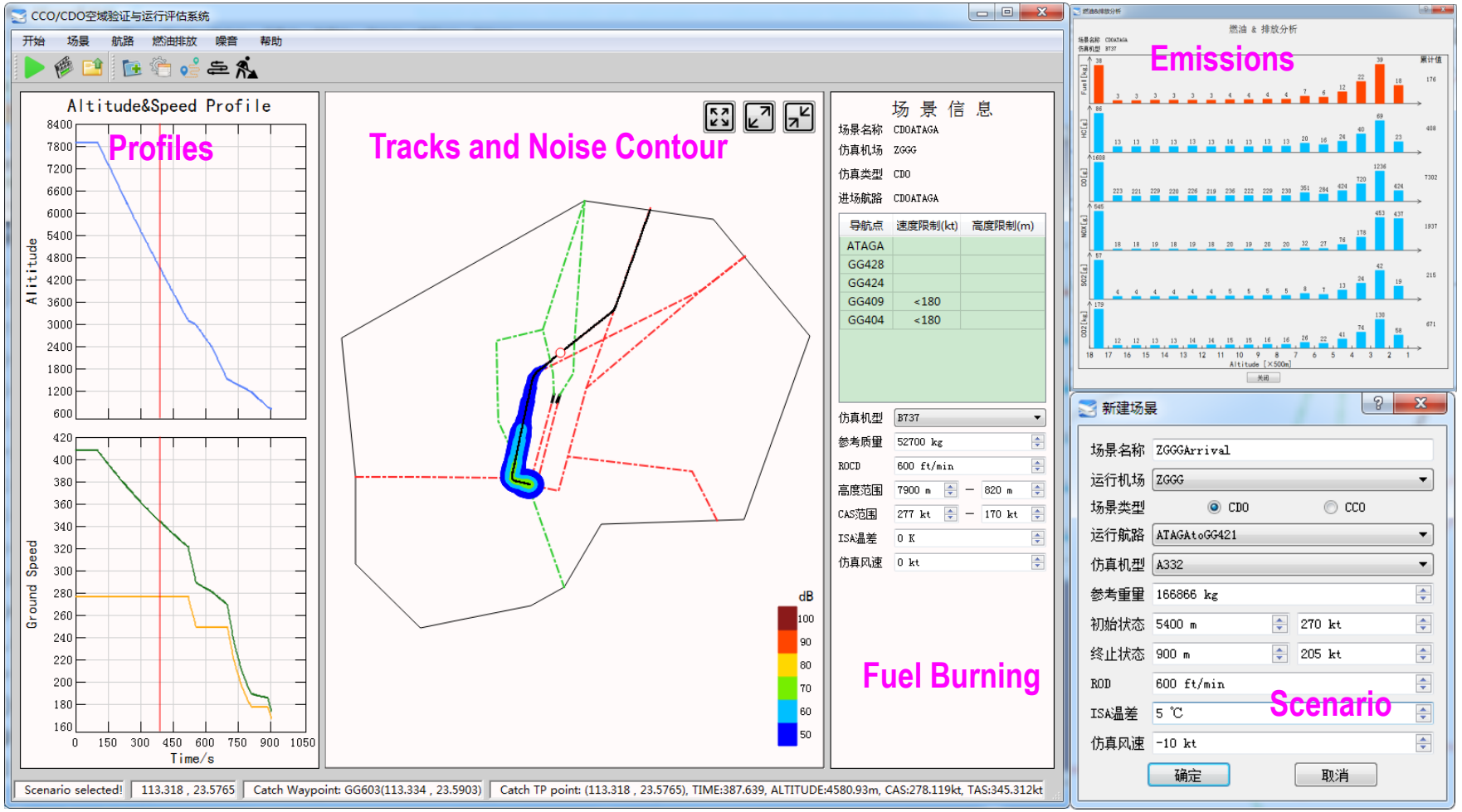
Data & Methods

- The data for evaluation
- The methods for evaluation

Results & Discussion

- What are the evaluation results
- What do these results stand for

Evaluation for Procedure Design / Validation / Operation



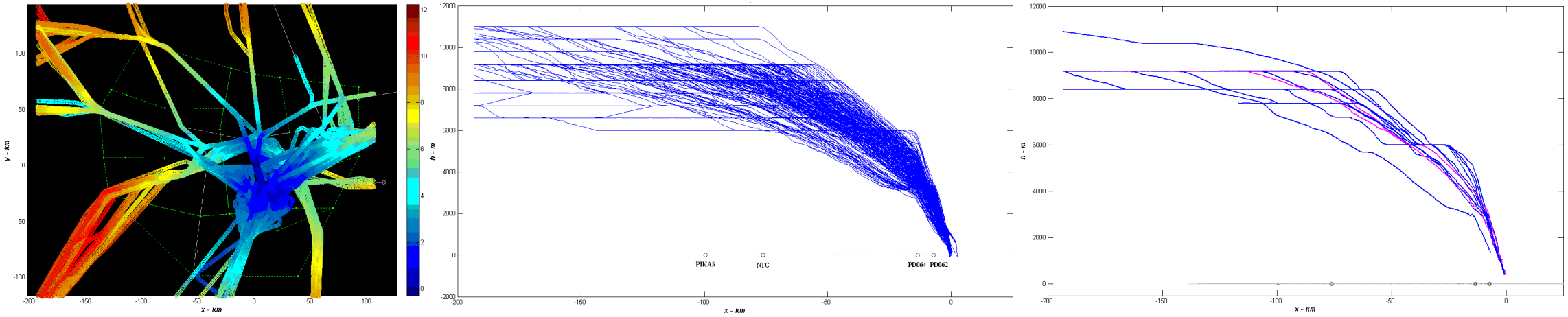
/01

Evaluation for Procedure Design

Evaluation for Procedure Design

Continuous Climb Operation (CCO)

An operation, enabled by airspace design, procedure design and ATC facilitation, in which an aircraft climbs continuously, to the greatest possible extent, by employing optimum climb engine thrust, at climb speeds until reaching the cruise flight level.



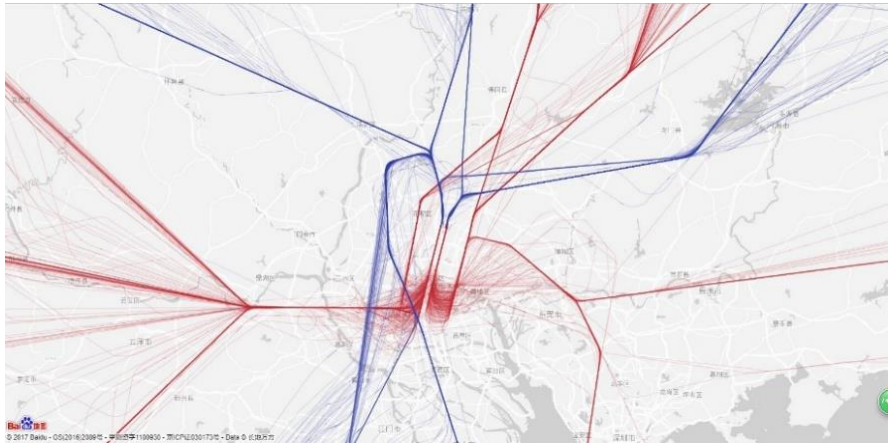
Altitude Profile (day)

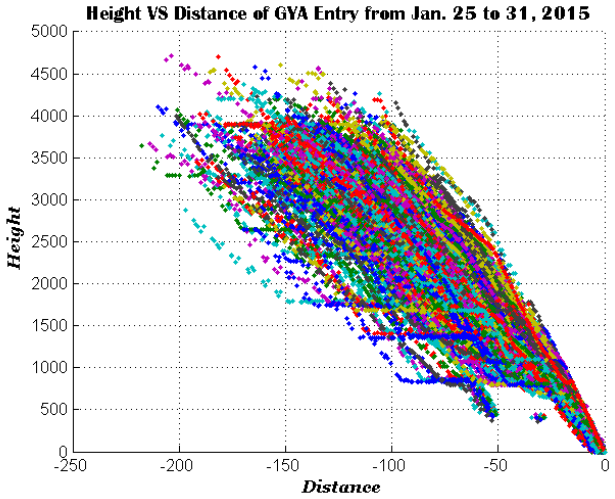
Altitude Profile (night)

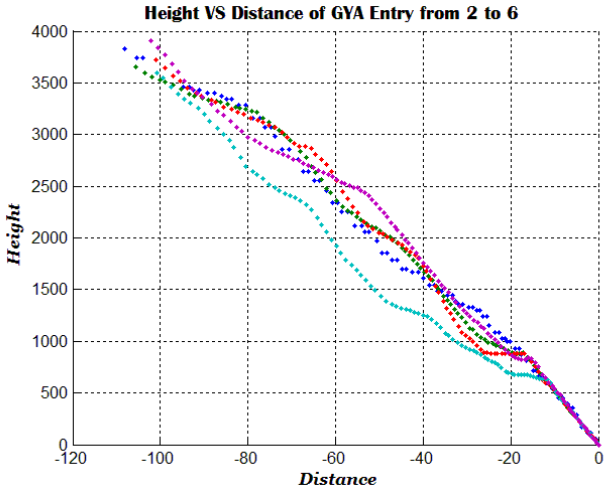
Evaluation for Procedure Design

Continuous Descent Operation (CDO)

An operation, enabled by airspace design, procedure design and ATC facilitation, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix /final approach point.







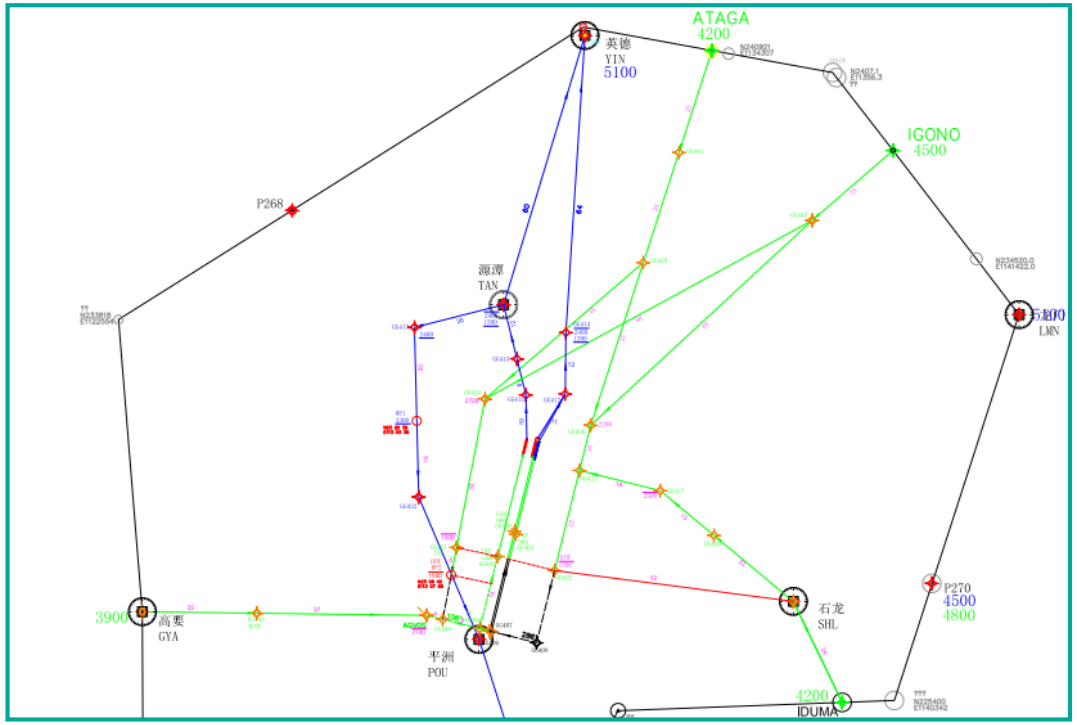
Evaluation for Procedure Design

Aim or Focus of Evaluation for CCO & CDO Design

- What about the Vertical (Altitude/Speed) Profiles of CCO and CDO – *Dose the designed procedure meet the requirements of all types of aircraft ?*

- What about the Vertical Profiles of CCO and CDO in the different conditions? (like aircraft masses, environmental conditions ...) CDO – *Is the designed procedure operated in the different conditions?*

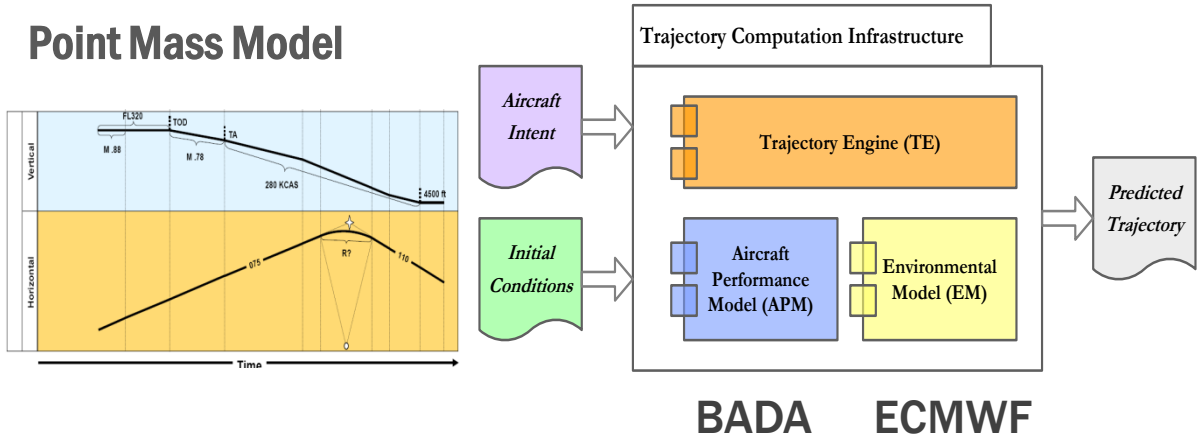
- Does the Letter of Agreement (LOA) or transferring separation still work in such new operations?



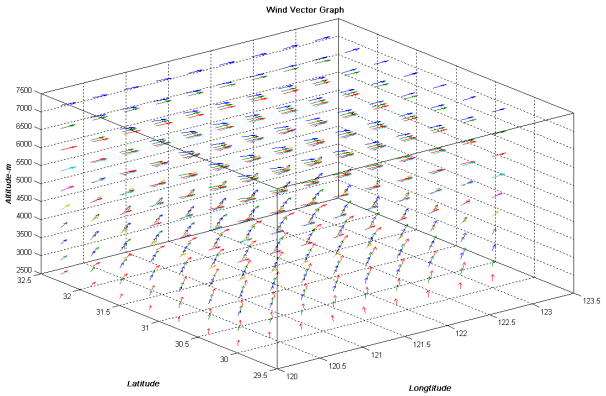
Evaluation for Procedure Design

Data and Methods of Evaluation for CCO & CDO Design

- What about the Vertical (Altitude/Speed) Profiles of CCO and CDO ?
- What about the Vertical Profiles of CCO and CDO in the different conditions?
- Does the Letter of Agreement (LOA) or transferring separation still work in such new operations?



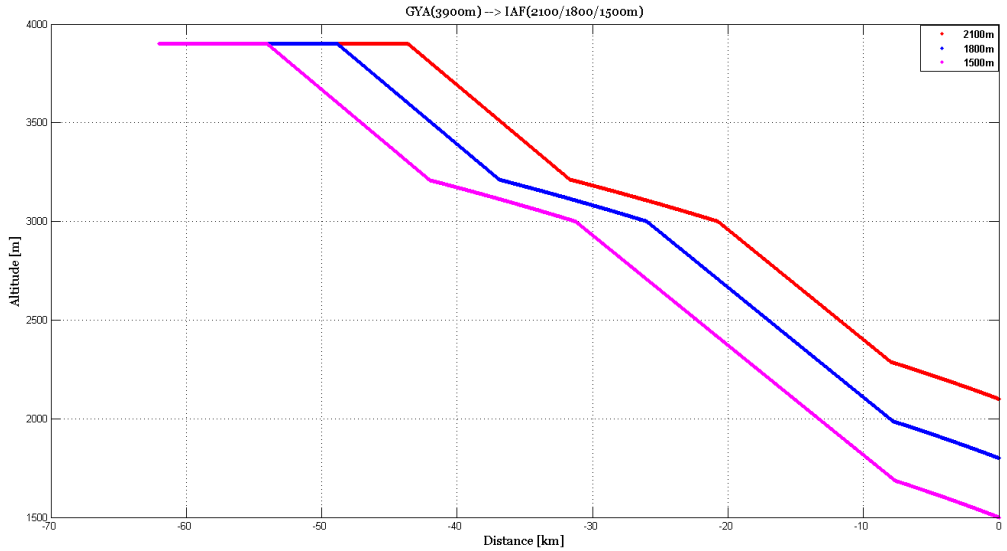
$$
\begin{aligned}
\dot{\xi} &= V_{\mathrm{TAS}}\cos(\psi)\cos(\gamma) + w_1 \\
\dot{\eta} &= V_{\mathrm{TAS}}\sin(\psi)\cos(\gamma) + w_2 \\
\dot{h} &= V_{\mathrm{TAS}}\sin(\gamma) \\
\dot{V} &= (T - D)/m - g\sin(\gamma) \\
\dot{\psi} &= g\tan\phi/V_{\mathrm{TAS}} \\
\dot{m} &= -\lambda T
\end{aligned}
$$

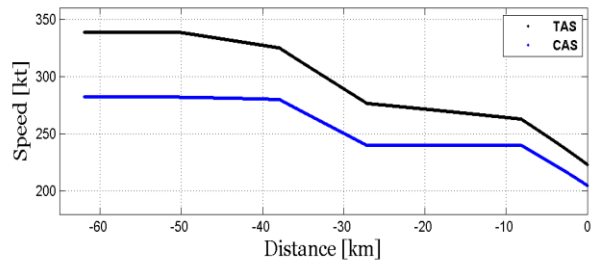


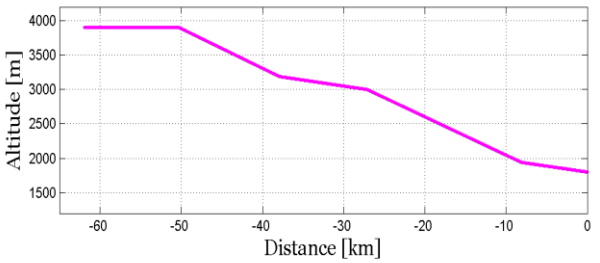
Evaluation for Procedure Design

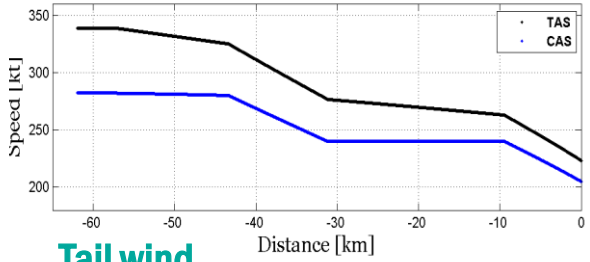
Results of Evaluation for CCO & CDO Design

- What about the Vertical (Altitude/Speed) Profiles of CCO and CDO ?
- What about the Vertical Profiles of CCO and CDO in the different conditions?

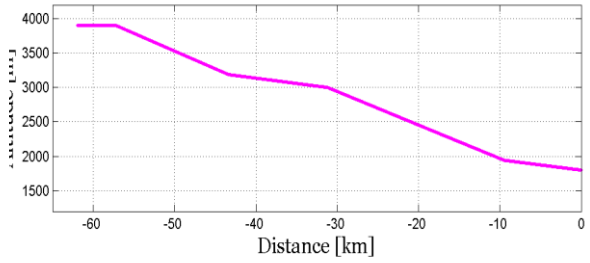








Tail wind

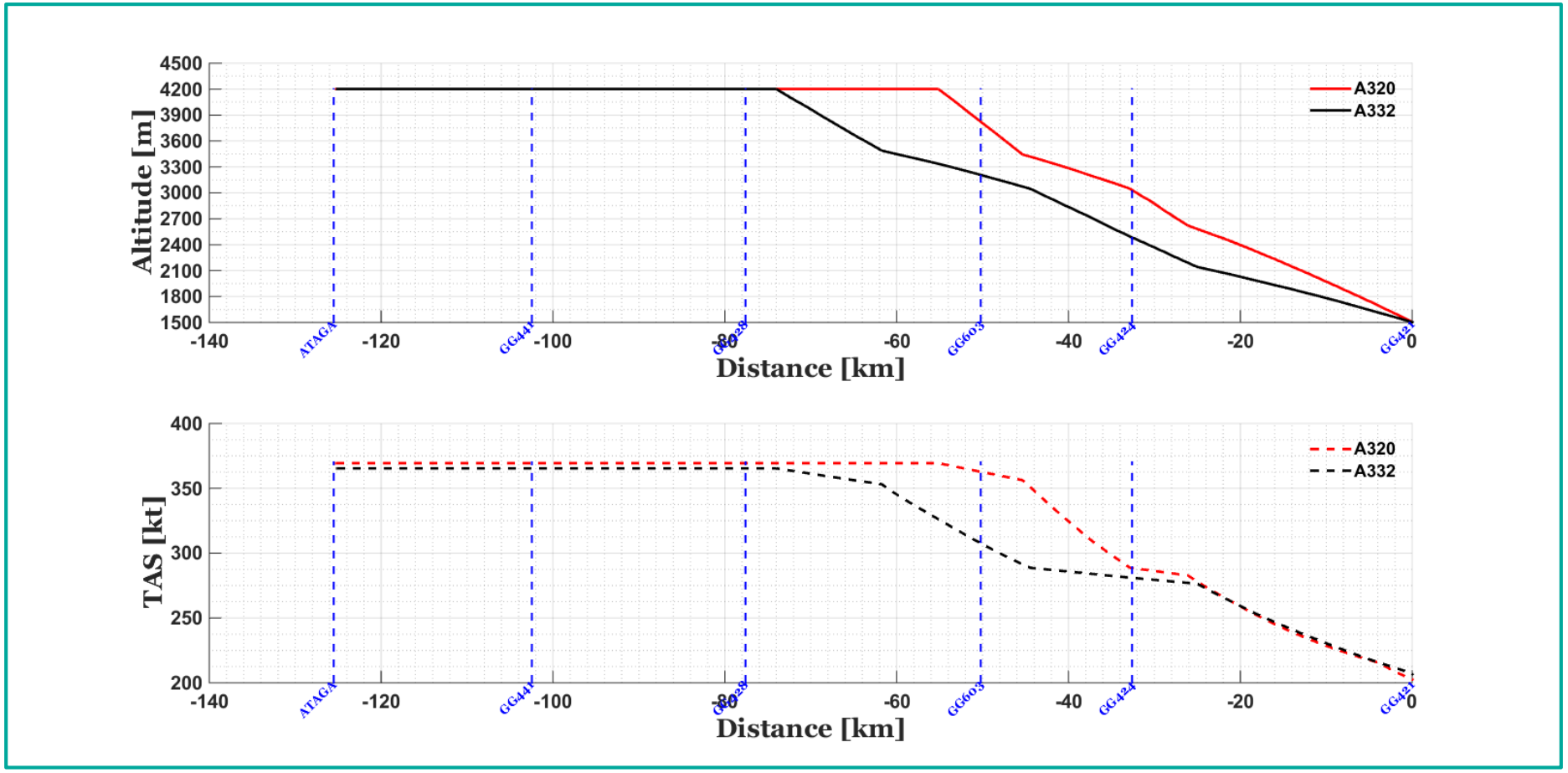


Different Restrictions

Different wind Information

Evaluation for Procedure Design

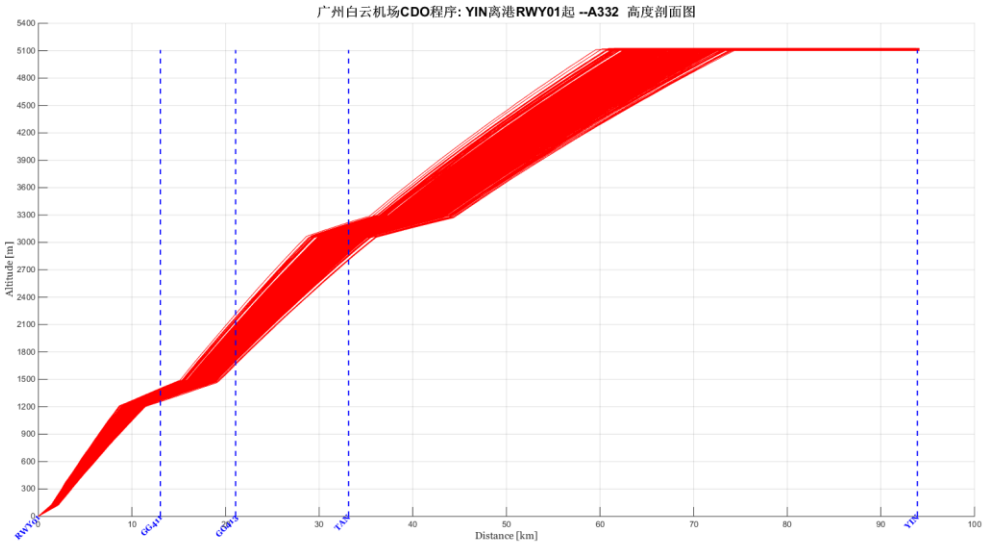
Results of Evaluation for CCO & CDO Design

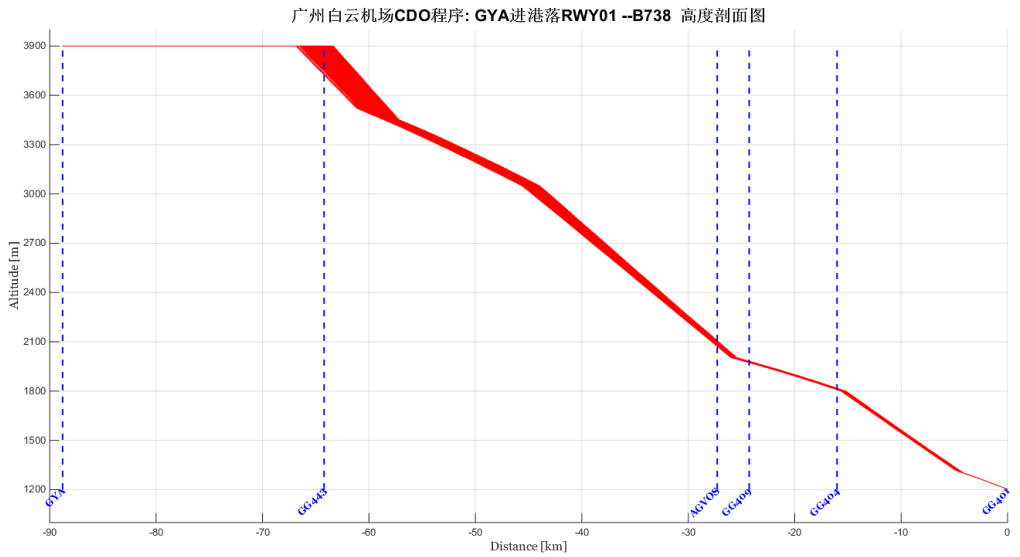


Evaluation for Procedure Design

Results of Evaluation for CCO & CDO Design

- What about the Vertical (Altitude/Speed) Profiles of CCO and CDO ?
- What about the Vertical Profiles of CCO and CDO in the different conditions?





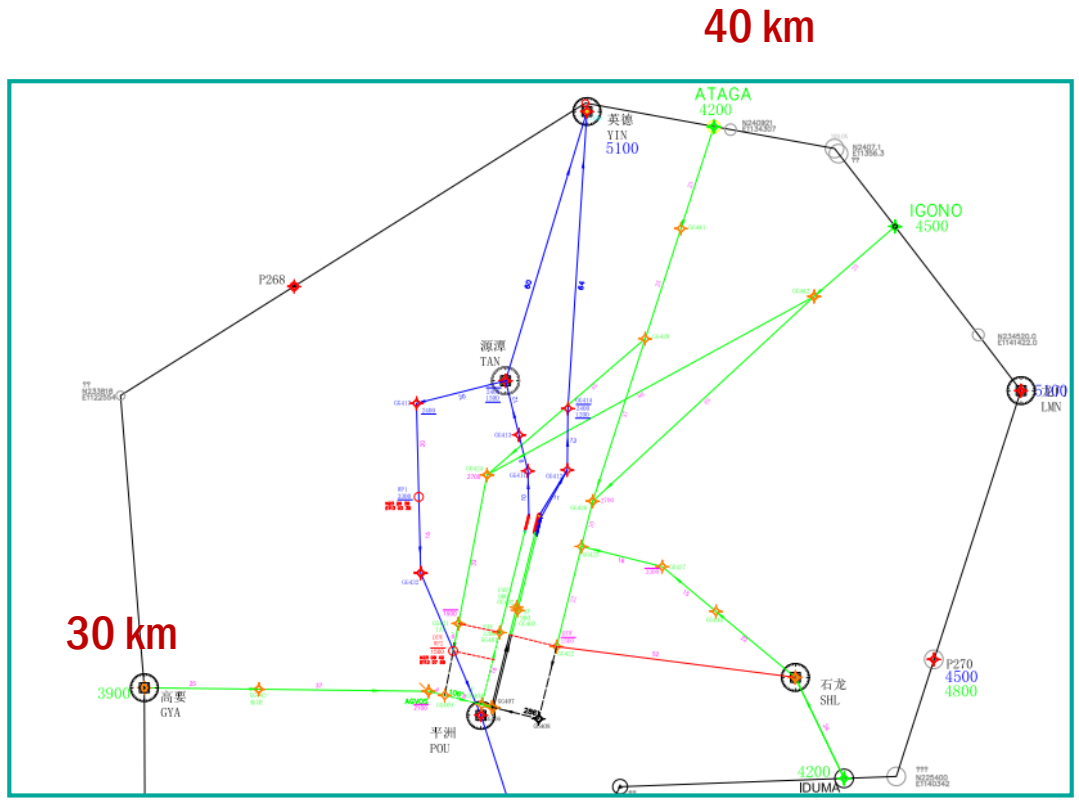
Evaluation for Procedure Design

Methods of Evaluation for CCO & CDO Design

- What about the Vertical (Altitude/Speed) Profiles of CCO and CDO

- What about the Vertical Profiles of CCO and CDO in the different conditions?

- Does the Letter of Agreement (LOA) or transferring separation still work in such new operations?



Evaluation for Procedure Design

Methods of Evaluation for CCO & CDO Design

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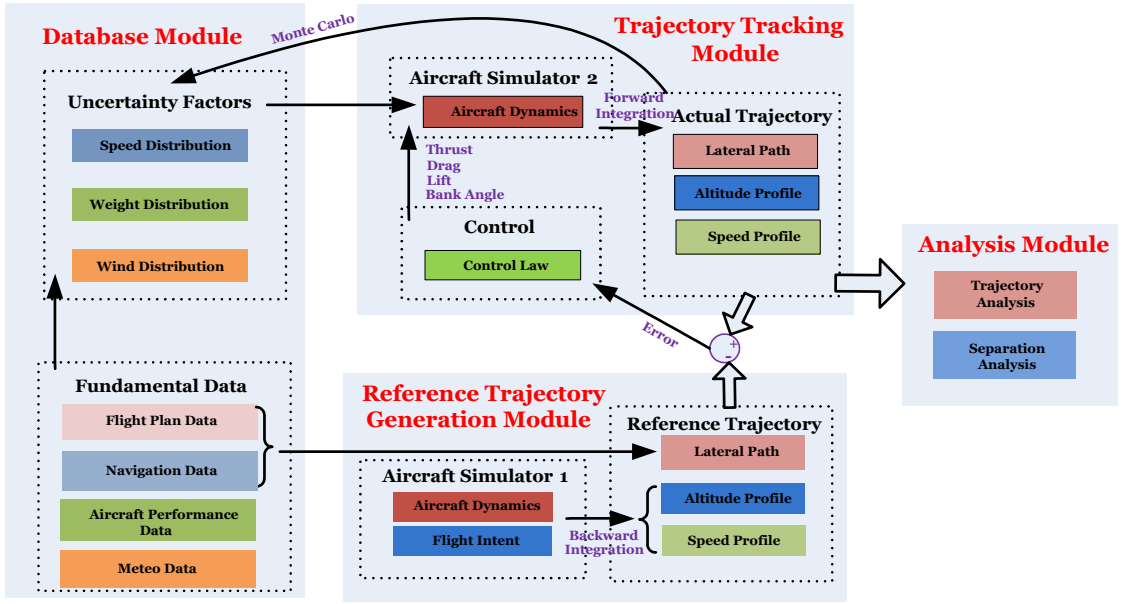
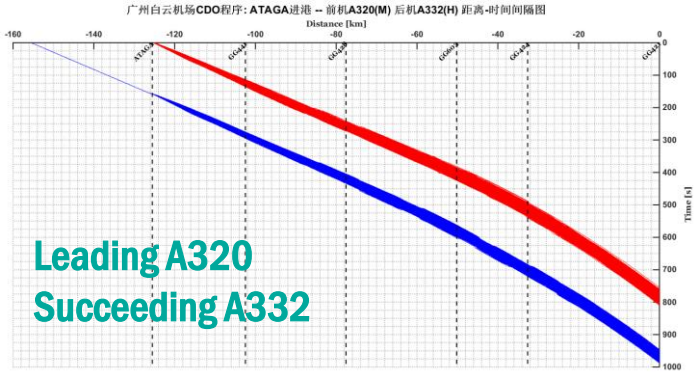


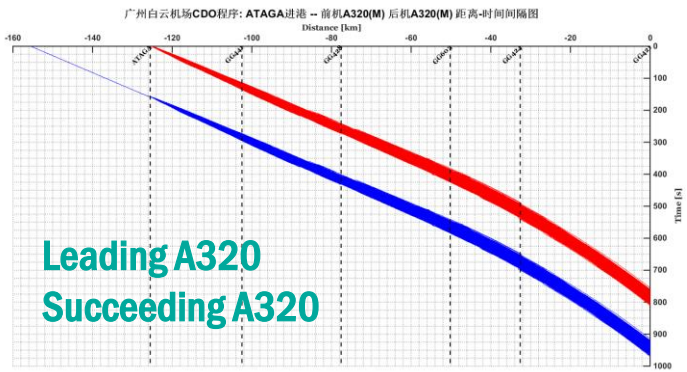
We adopted *Monte Carlo Simulation* and *statistical analysis* to demonstrate that such LOA still work.

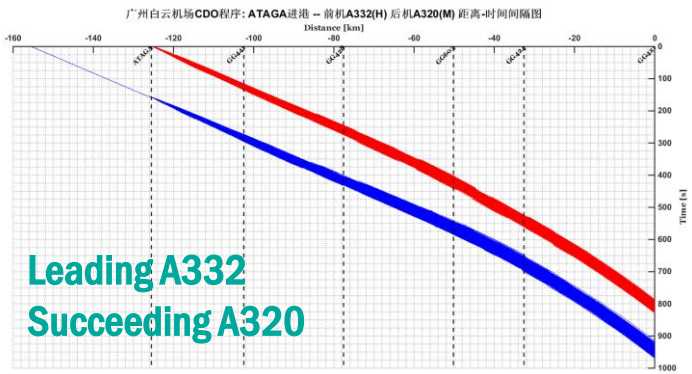
Evaluation for Procedure Design

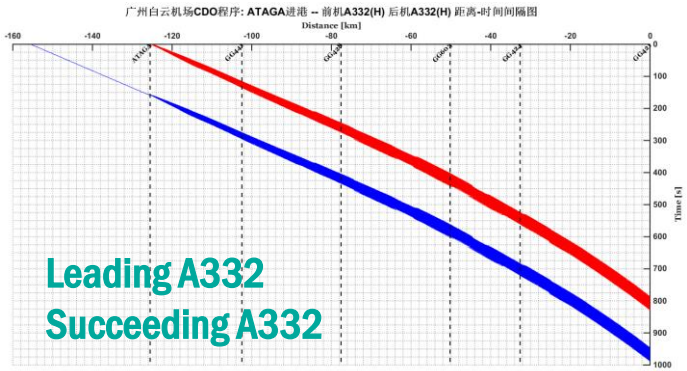
Results of Evaluation for CCO & CDO Design

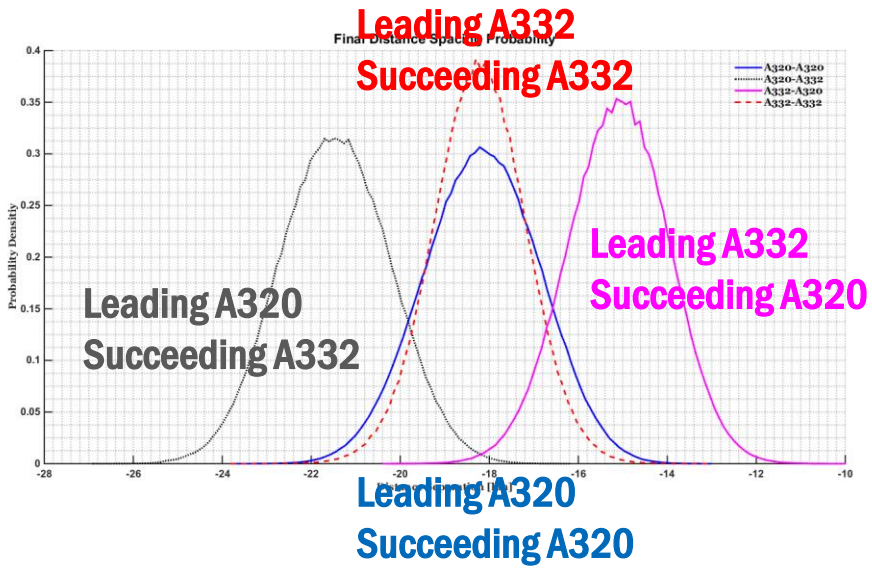
- Does the Letter of Agreement (LOA) or transferring separation still work in such new operations ?



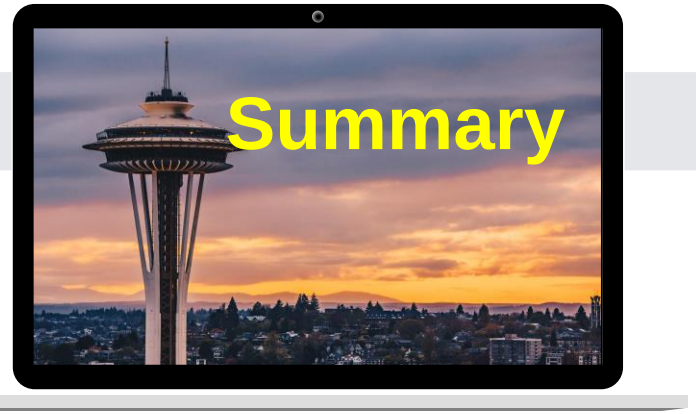








The current transferring separation still work in such new operations !



Flight Procedure Design, Validation, and operation

Multiple Evaluation	Aim & Focus	Data & Methods
Design	Vertical Profiles / Separation / Potential Benefits (to predict the Potential Issues that may be encountered in future)	Computer Simulation (Tool Developed by ourselves)

/02

Evaluation for Procedure Validation

Evaluation for Procedure Validation

Aim or Focus of CCO & CDO Validation

- Help the pilots to be familiar with the CCO and CDO.
- Help us verify our computer simulation methods.
- Help the controllers to be familiar with the CCO and CDO.
- Help all stakeholders to cooperate with each other during implementing CCO and CDO.

Evaluation for Procedure Validation

Methods (I Flight simulator) and Results of Evaluation for CCO & CDO Validation

- Help the pilots to be familiar with the CCO and CDO.
- Help us verify our computer simulation methods.

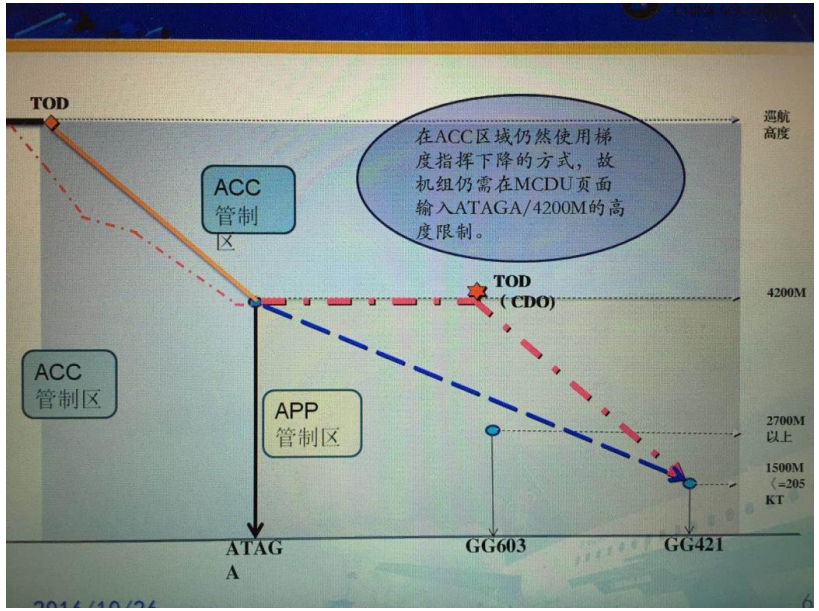


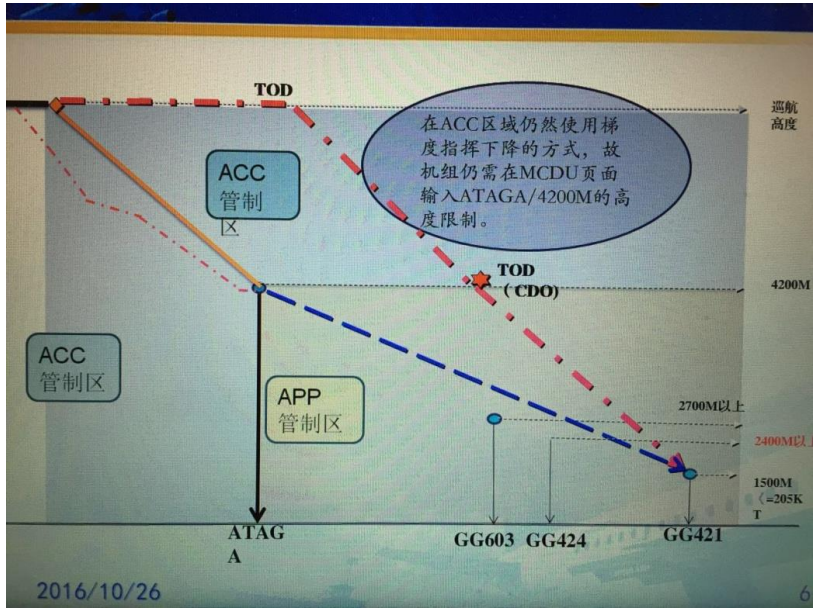
We also invited controllers to participate into the flight simulation. *(communication, mutual understanding)*

Evaluation for Procedure Validation

Methods (I Flight simulator) and Results of Evaluation for CCO & CDO Validation

- Help the pilots to be familiar with the CCO and CDO.
- Help us verify our computer simulation methods.



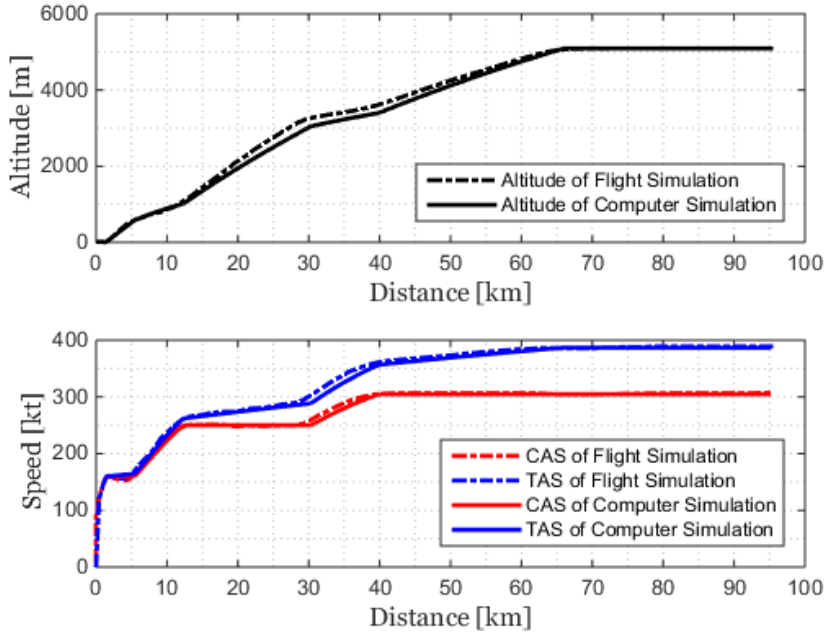


Evaluation for Procedure Validation

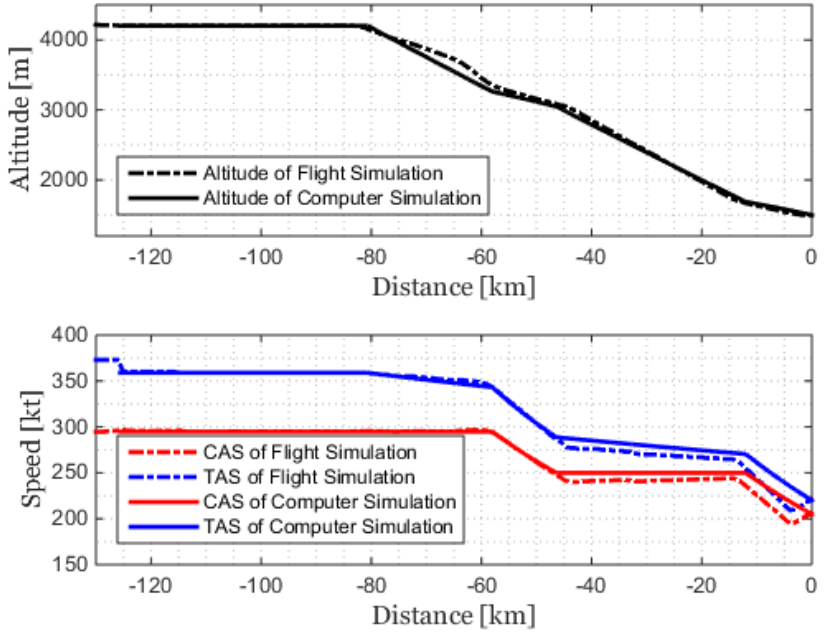
Methods (I Flight simulator) and Results of Evaluation for CCO & CDO Validation

- Help the pilots to be familiar with the CCO and CDO.
- Help us verify our computer simulation methods.

YIN - CCO



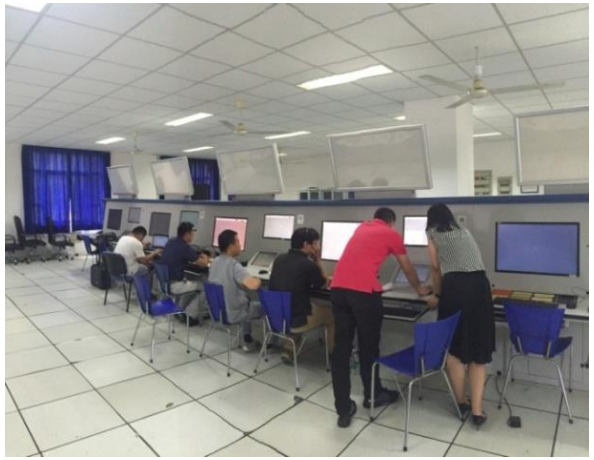
ATAGA - CDO

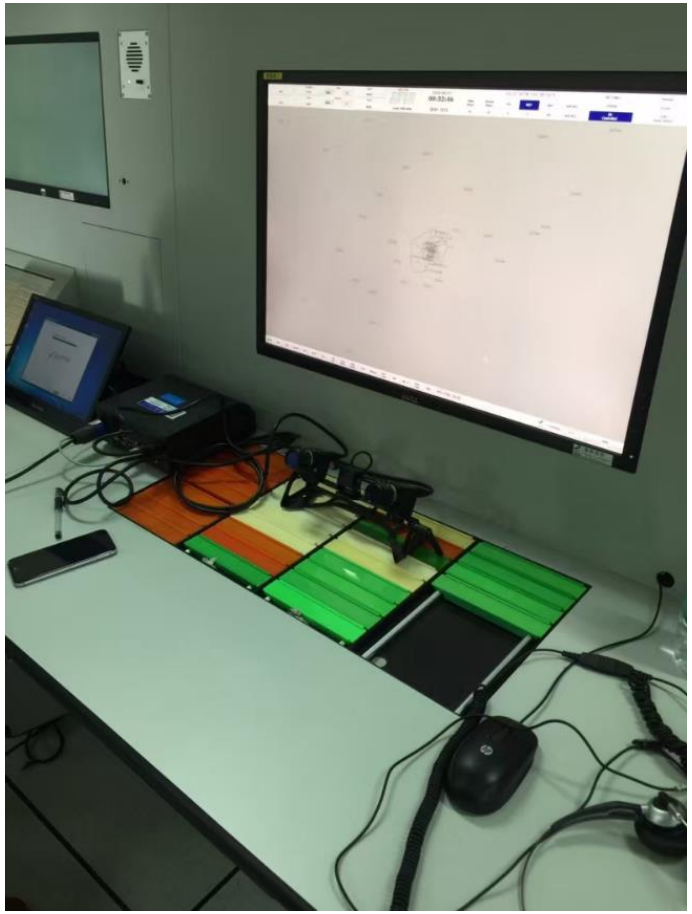


Evaluation for Procedure Validation

Methods (II radar control simulator) and Results of Evaluation for CCO & CDO Validation

- Help the controllers to be familiar with the CCO and CDO.

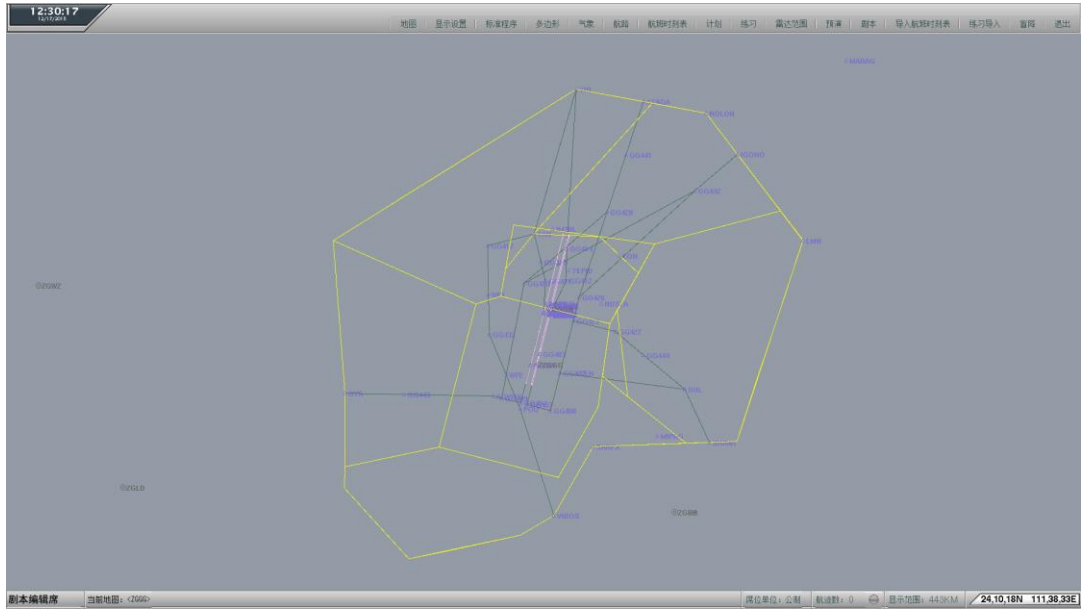


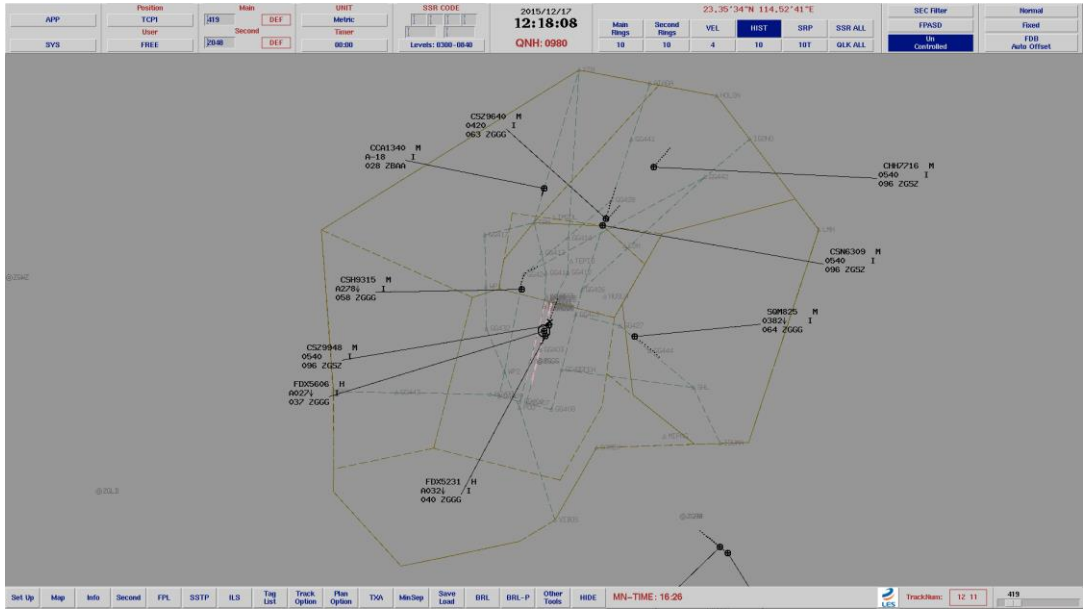


- *We upgrade the radar control simulator, which now could generate the CCO/CDO profile based on the results of our computer simulation.*
- *We analyze the workload of controllers based on Eye Tracking Instrument.*

Evaluation for Procedure Validation

- **Methods (II radar control simulator) and Results of Evaluation for CCO & CDO Validation**
  - Help the controllers to be familiar with the CCO and CDO.



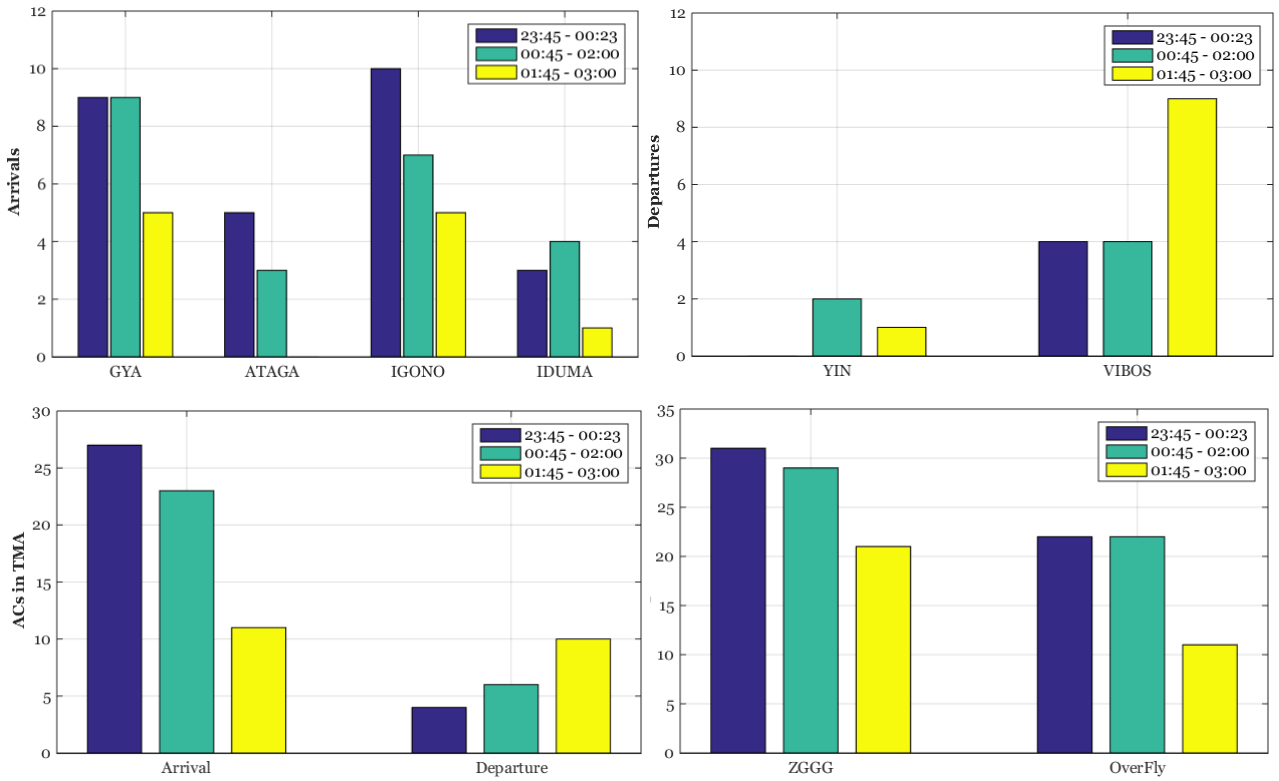


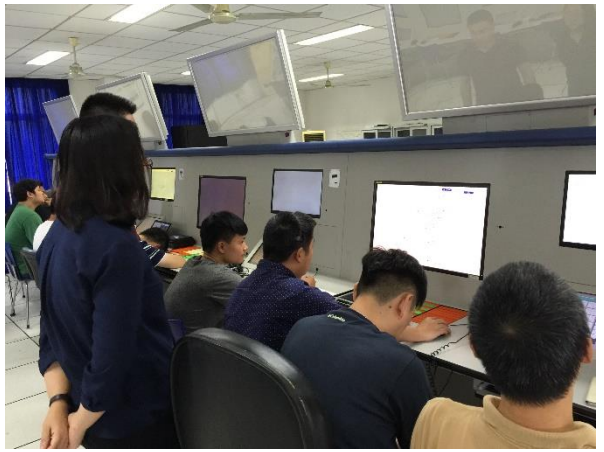
Evaluation for Procedure Validation

Methods (II radar control simulator) and Results of Evaluation for CCO & CDO Validation

- Help the controllers to be familiar with the CCO and CDO.

3 Scenarios



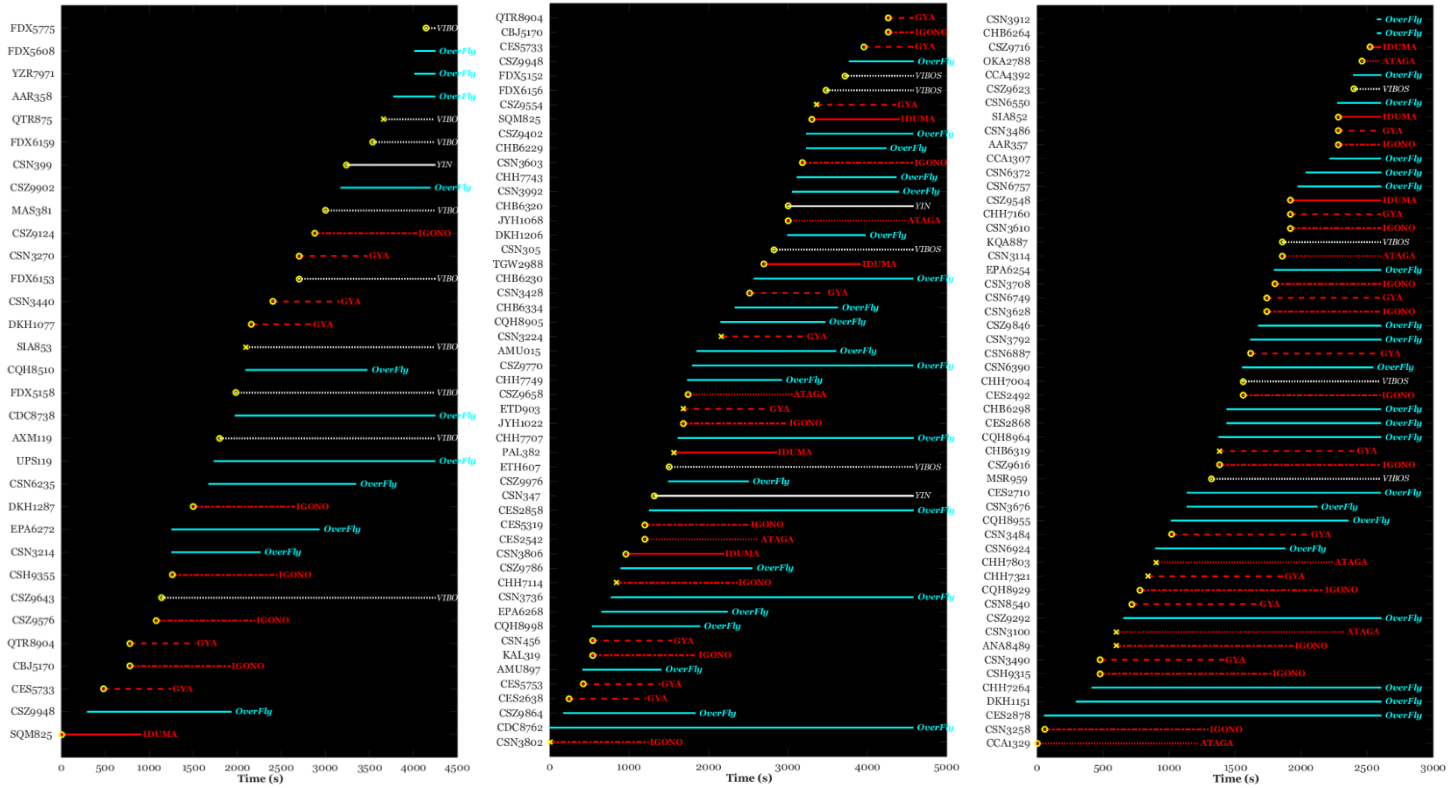


Evaluation for Procedure Validation

Methods (II radar control simulator) and Results of Evaluation for CCO & CDO Validation

- Help the controllers to be familiar with the CCO and CDO.

- *We design three different scenarios.*
- *If the air traffic is low, that is perfect.*
- *Otherwise, the implementation rate is decreasing and the controller's workload is increasing.*

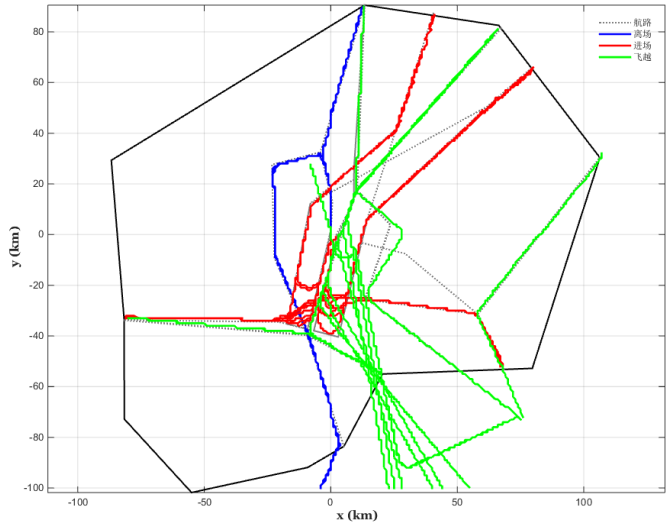


Evaluation for Procedure Validation

Methods (II radar control simulator) and Results of Evaluation for CCO & CDO Validation

- Help the controllers to be familiar with the CCO and CDO.

  - *We design three different scenarios. If the air traffic is low, that is perfect. Otherwise, the implementation rate is decreasing and the controller's workload is increasing.*



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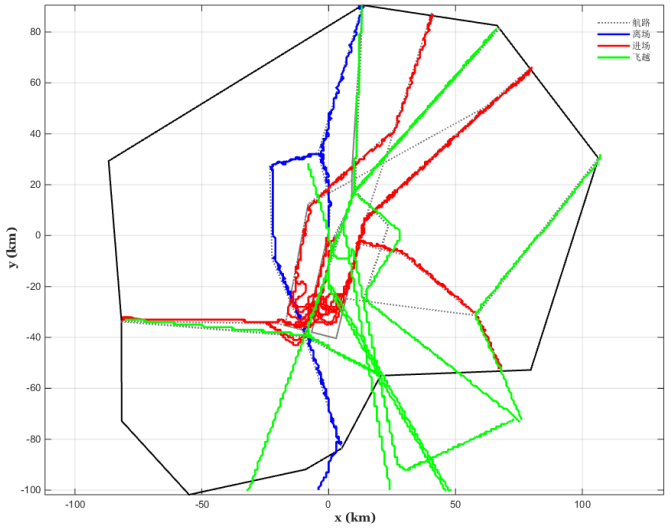

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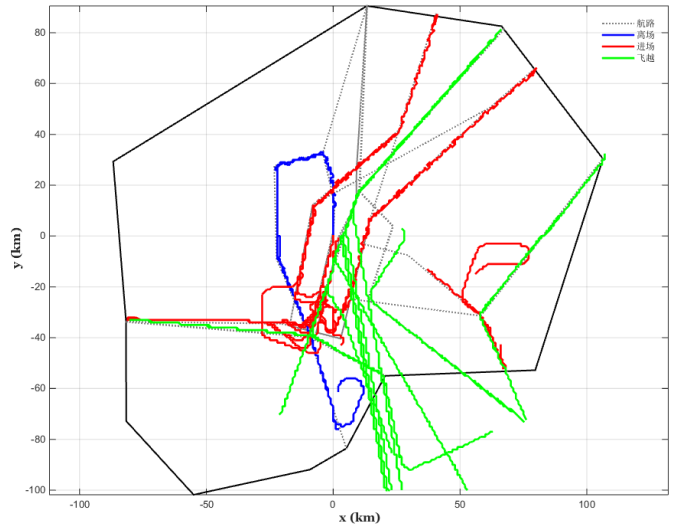


23:45-00:23

Evaluation for Procedure Validation

Methods (III test flight) and Results of Evaluation for CCO & CDO Validation

- Help all stakeholders to cooperate with each other during implementing CCO and CDO.

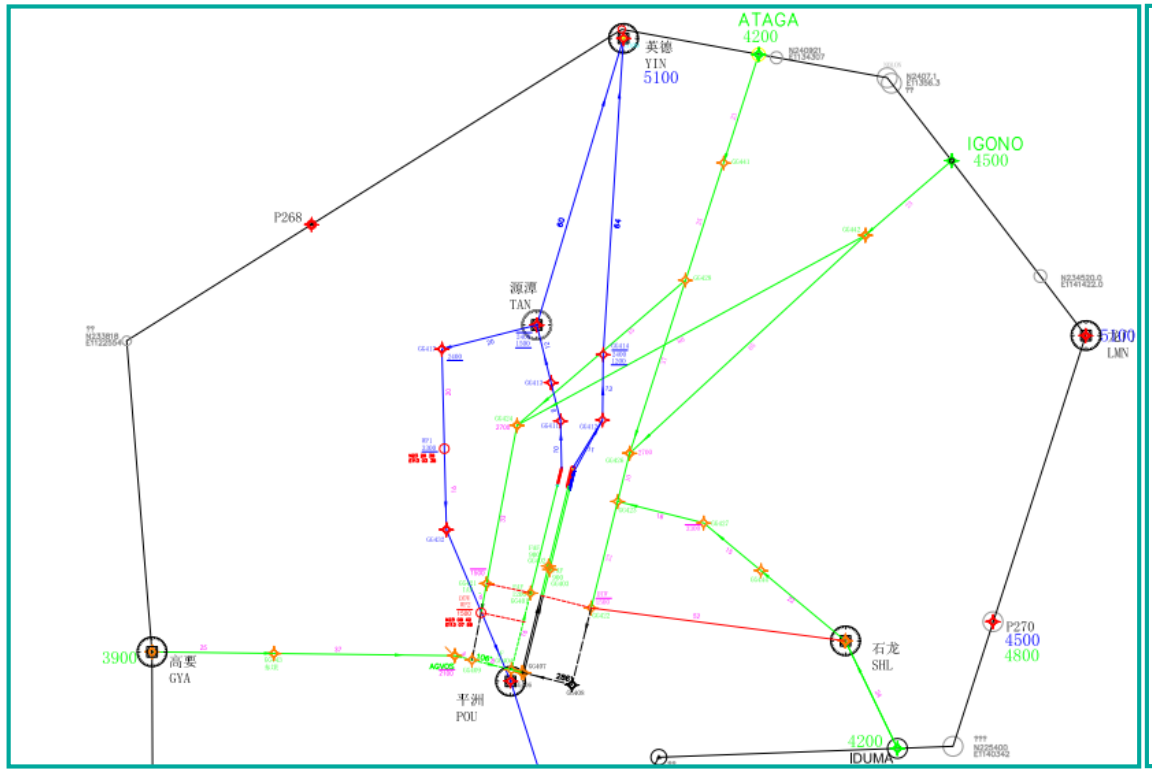


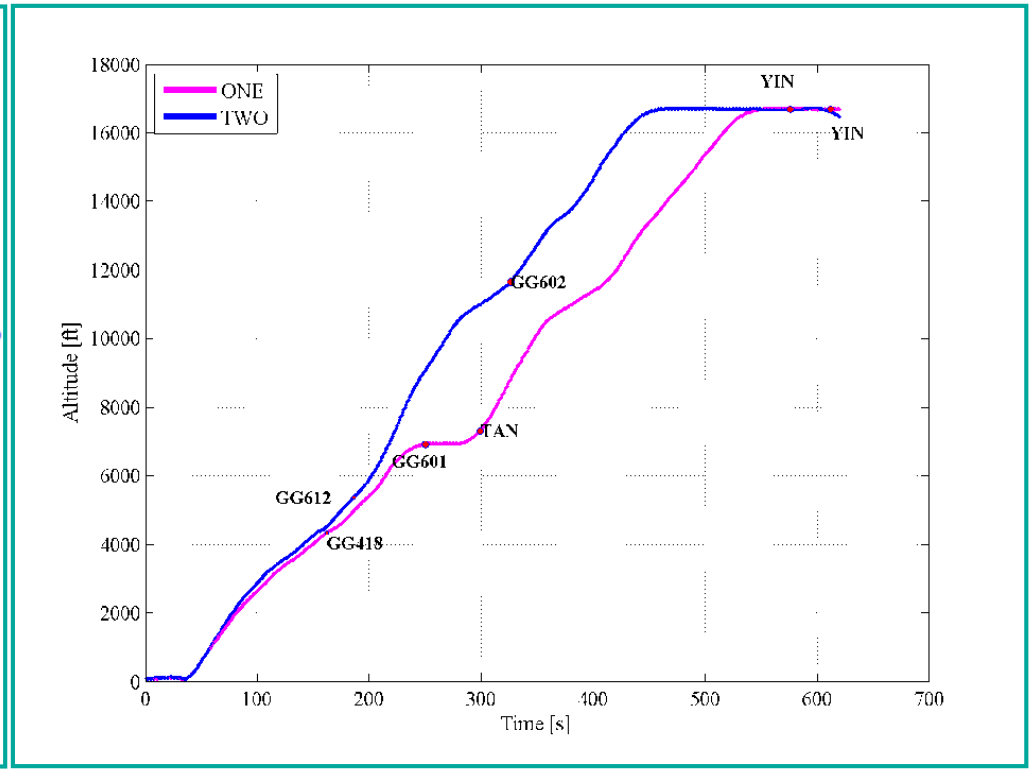



Evaluation for Procedure Validation

Methods (III test flight) and Results of Evaluation for CCO & CDO Validation

- Help all stakeholders to cooperate with each other during implementing CCO and CDO.

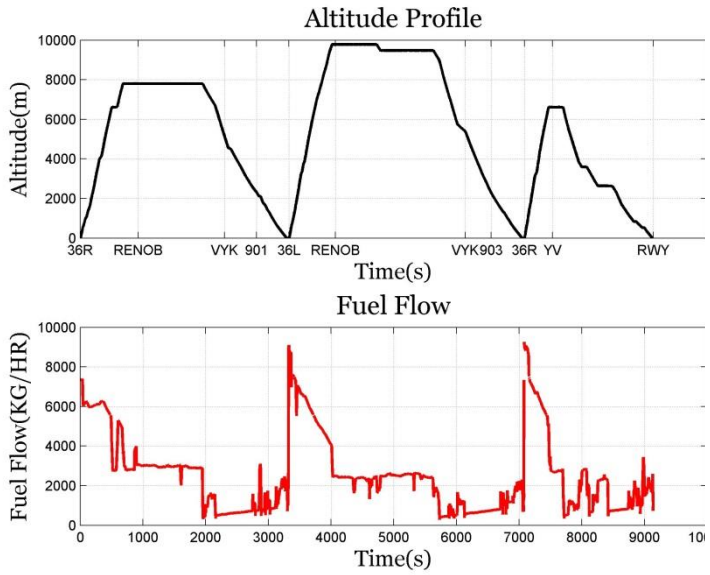




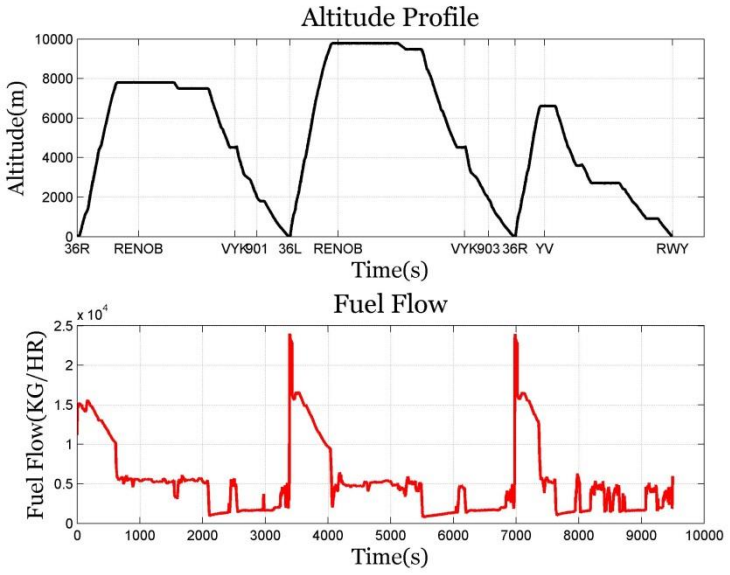
Evaluation for Procedure Validation

Methods (III test flight) and Results of Evaluation for CCO & CDO Validation

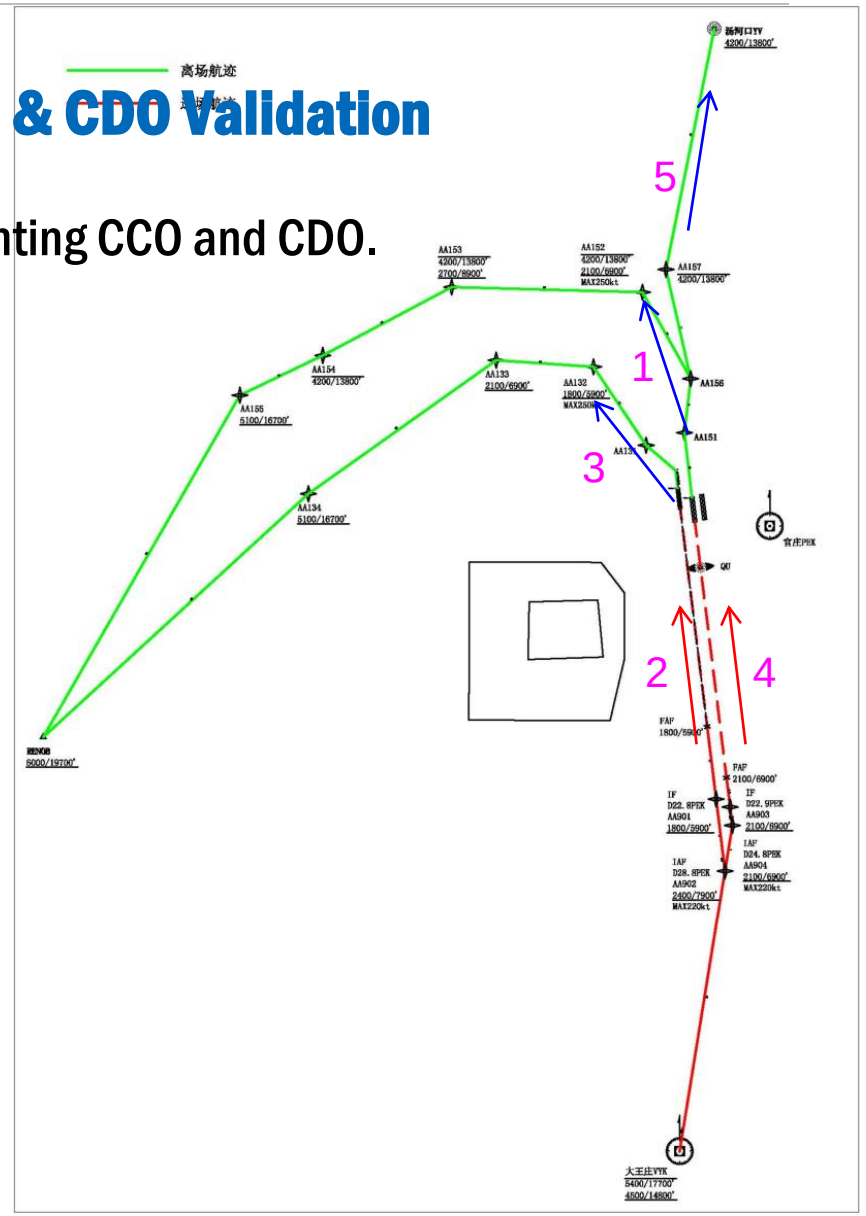
- Help all stakeholders to cooperate with each other during implementing CCO and CDO.

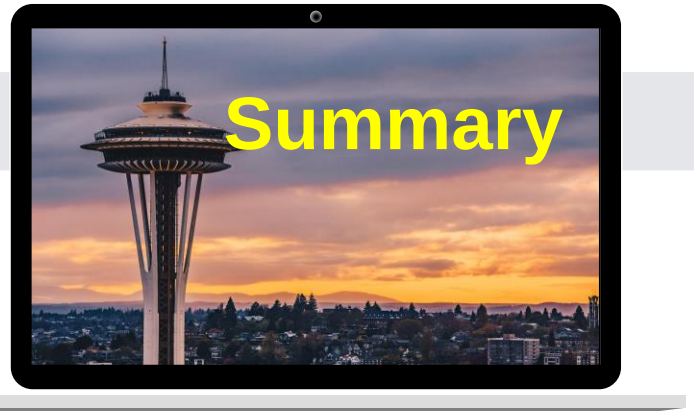


B738



A332





Flight Procedure Design, Validation, and operation

Multiple Evaluation	Aim & Focus	Data & Methods
Design	Vertical Profiles / Separation / Potential Benefits (to predict the Potential Issues that may be encountered in future)	Computer Simulation (Tool Developed by ourselves)
Validation	Where should be focused on / when to operate (workload of ATCOs)	Control Simulator
	How about the designed procedure / benefits / our tool	Flight Simulator
	Help all the stakeholders to be familiar with the CCO and CDO.	Test flight

/03

Evaluation for Procedure Operation

Evaluation for Procedure Operation

Aim or Focus of Evaluation for CCO & CDO Operation

- Help relevant authorities and all stakeholders to be aware of the benefits of CCO and CDO in China.

(fuel consumption, noise contours, and emissions based on the QAR data).

- Help controllers and pilots to be aware of the achievements of implementation.

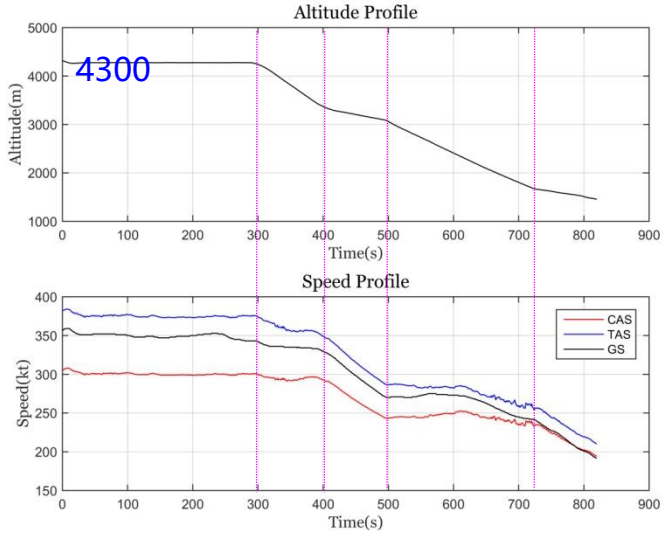
Evaluation for Procedure Operation

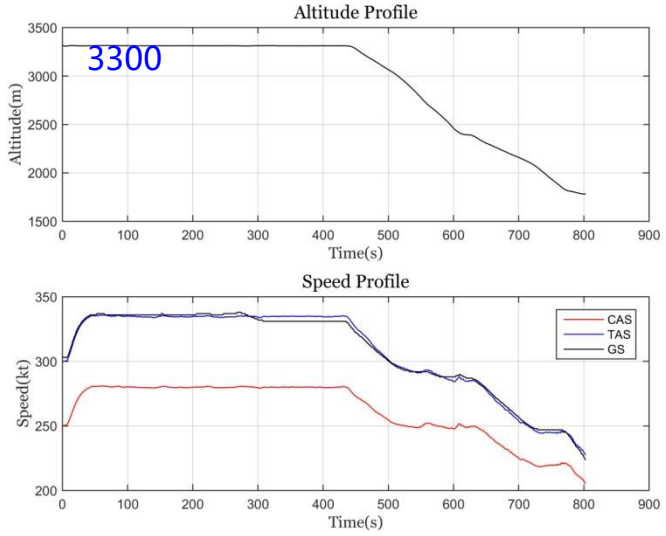
Methods and Results of Evaluation for CCO & CDO Operation

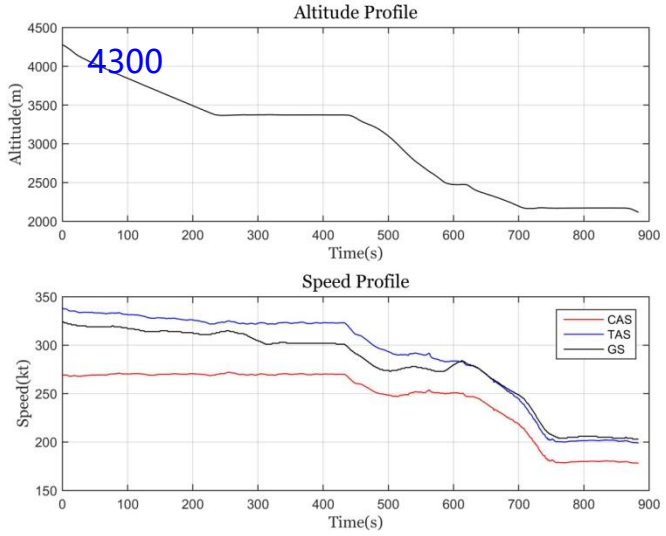
- Help relevant authorities and all stakeholders to be aware of the benefits of CCO and CDO in China.

Date	Flight	Dep Airport	Reg.	Engine	Operation	Time (s)	Fuel (kg)	Weight (kg)	Reduction (kg)
20170112	CSN600	KJFK	B-7185	GE90-115BL	CDO	819	877.3	225707.6	
20170103	CSN3162	ZBAA	B-7185	GE90-115BL	CDO (Low Alt.)	802	1054.8	211482.9	177.5
20170109	CSN3116	ZBAA	B-2099	GE90-115BL	Step	883	1018.9	207999.3	141.6

B773



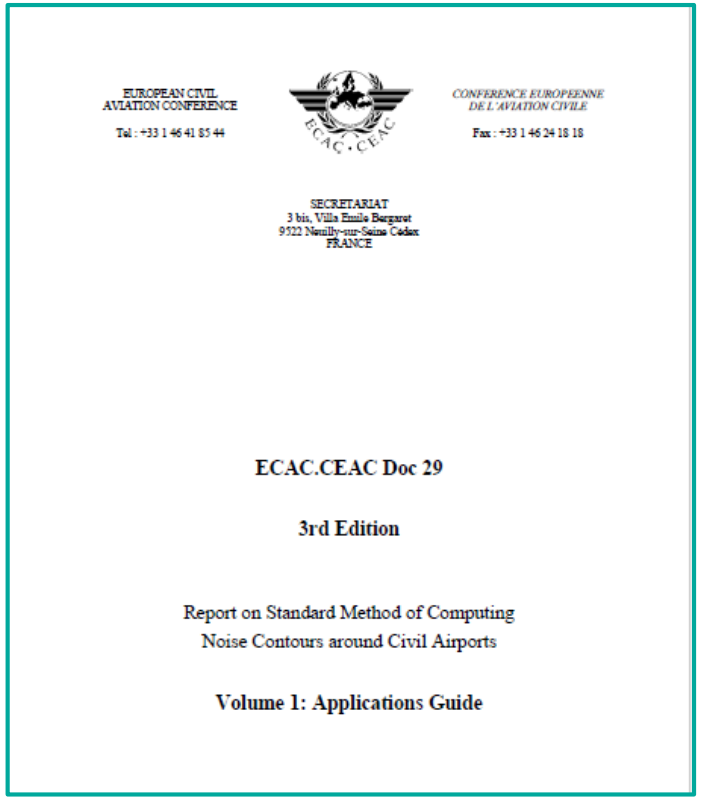


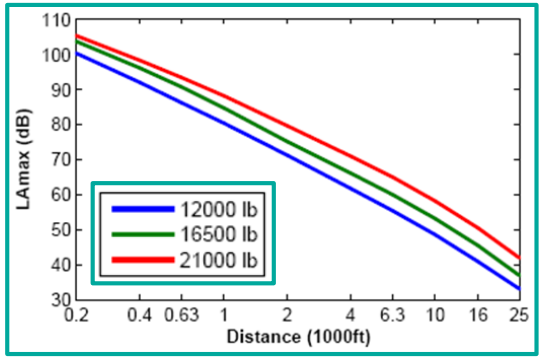


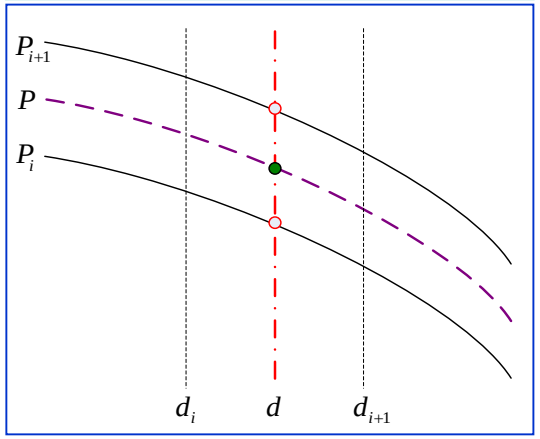
Evaluation for Procedure Operation

Methods and Results of Evaluation for CCO & CDO Operation

- Help relevant authorities and all stakeholders to be aware of the benefits of CCO and CDO in China.





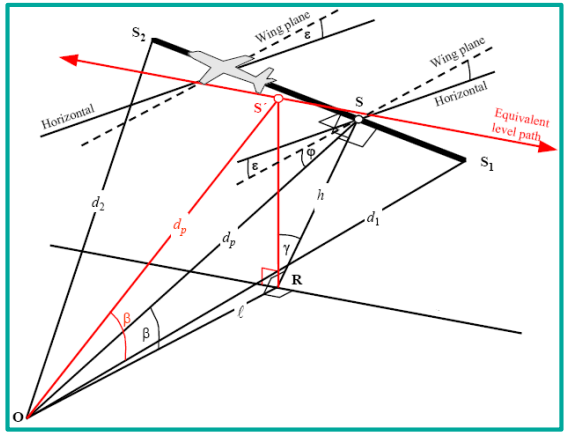


Thrust Estimation

$$(Thr - Drag)\cdot s = mgh + \frac{1}{2}mv^2$$

$$(Thr - Drag)\cdot v = mg\frac{dh}{dt} + mv\frac{dv}{dt}$$

$$Thr - Drag = mg\cdot\sin(FPA) + m\frac{dv}{dt}$$



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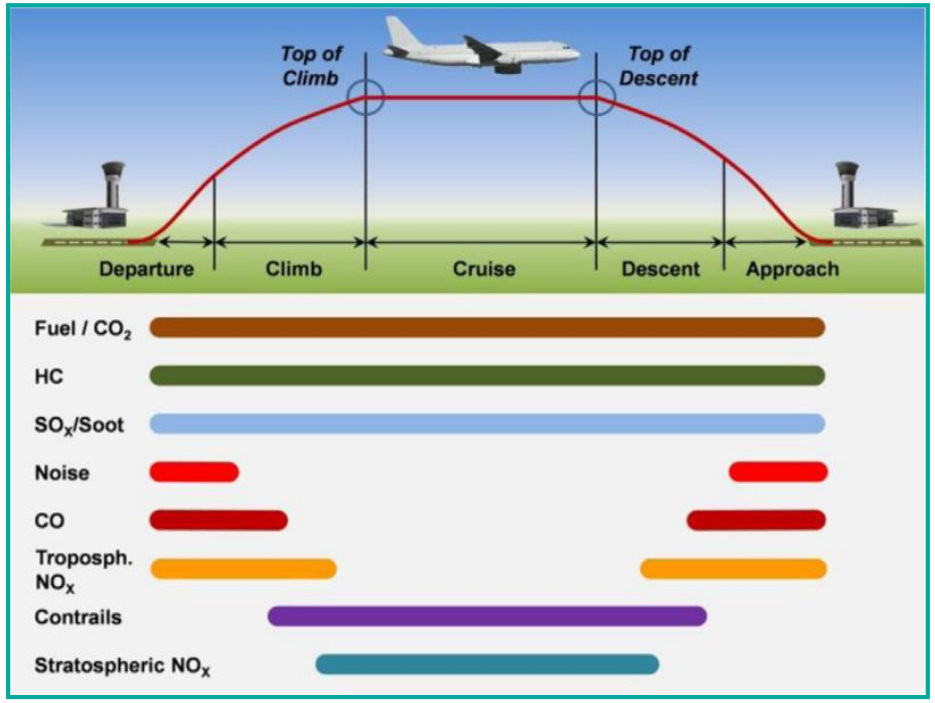

《Engine Exhaust Emissions Data Bank》

	FF (KG/SEC)	HC (G/KG)	CO (G/KG)	No_x (G/KG)
T/O	2.449	0.11	0.08	32.5
C/O	1.981	0.17	0.14	26.4
APP	0.647	0.25	0.90	11.6
IDLE	0.188	0.66	11.6	5.0

$$MF_t = \frac{F_t}{\delta}\theta^{3.8}e^{0.2M^2}, \quad Q = \int_{t_0}^{T_t}(MF_t \times d_t)$$

$$MEI_j = \begin{cases} \dfrac{EI_j \times \theta^{3.3}}{\delta^{1.02}}, j = HC, CO \\ \dfrac{EI_j \times \theta^{0.51}}{\delta^{1.65}} \exp\left[19 \times \left(0.0063 - \dfrac{0.622\varphi P_V}{P - \varphi P_V}\right)\right], j = NO_x \end{cases}$$

$$E_j = n \times Q \times MEI_j, \quad j = HC, CO, NO_x$$

Evaluation for Procedure Operation

Methods and Results of Evaluation for CCO & CDO Operation

- Help controllers and pilots to be aware of the termination of some trials.
  - *Due to the conflict between two arrivals*
  - *Due to the conflict between arrival and departures*
  - *Due to the aircraft operations (the old plane without the VNAV function)*

Evaluation for Procedure Operation

Methods and Results of Evaluation for CCO & CDO Operation

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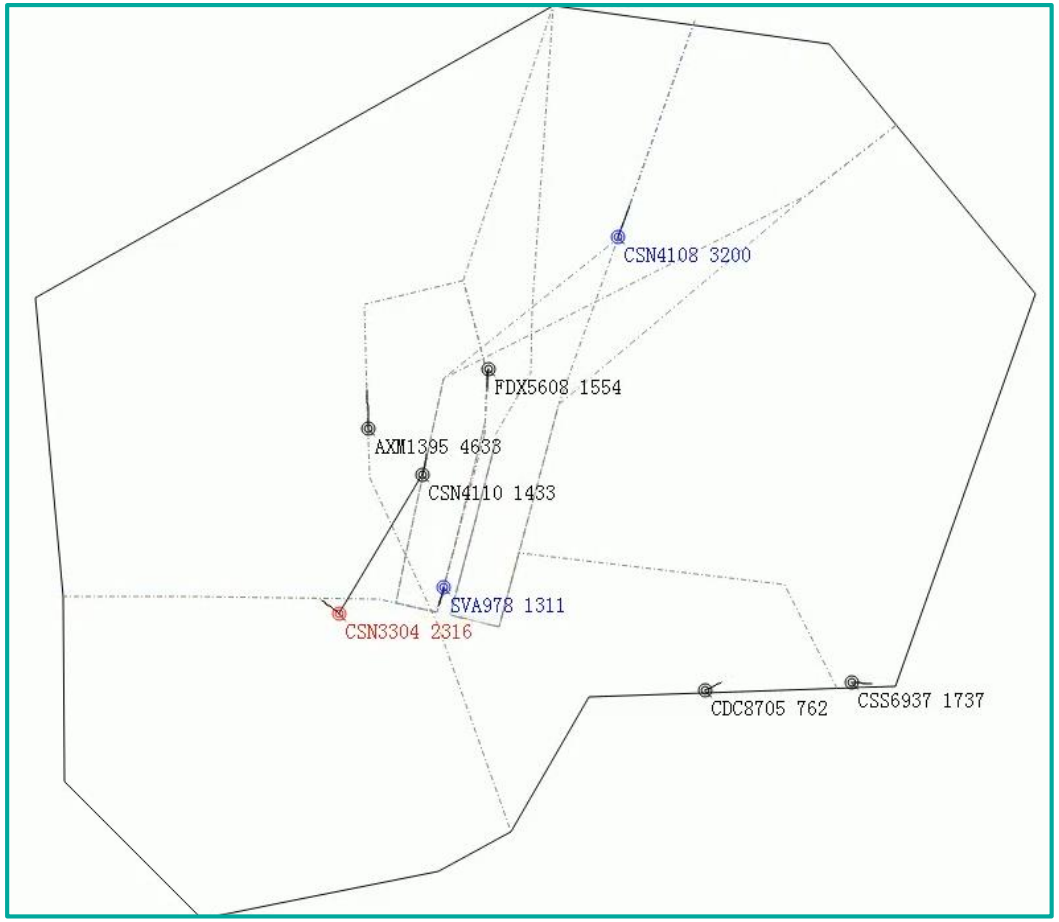

Evaluation for Procedure Operation

Methods and Results of Evaluation for CCO & CDO Operation

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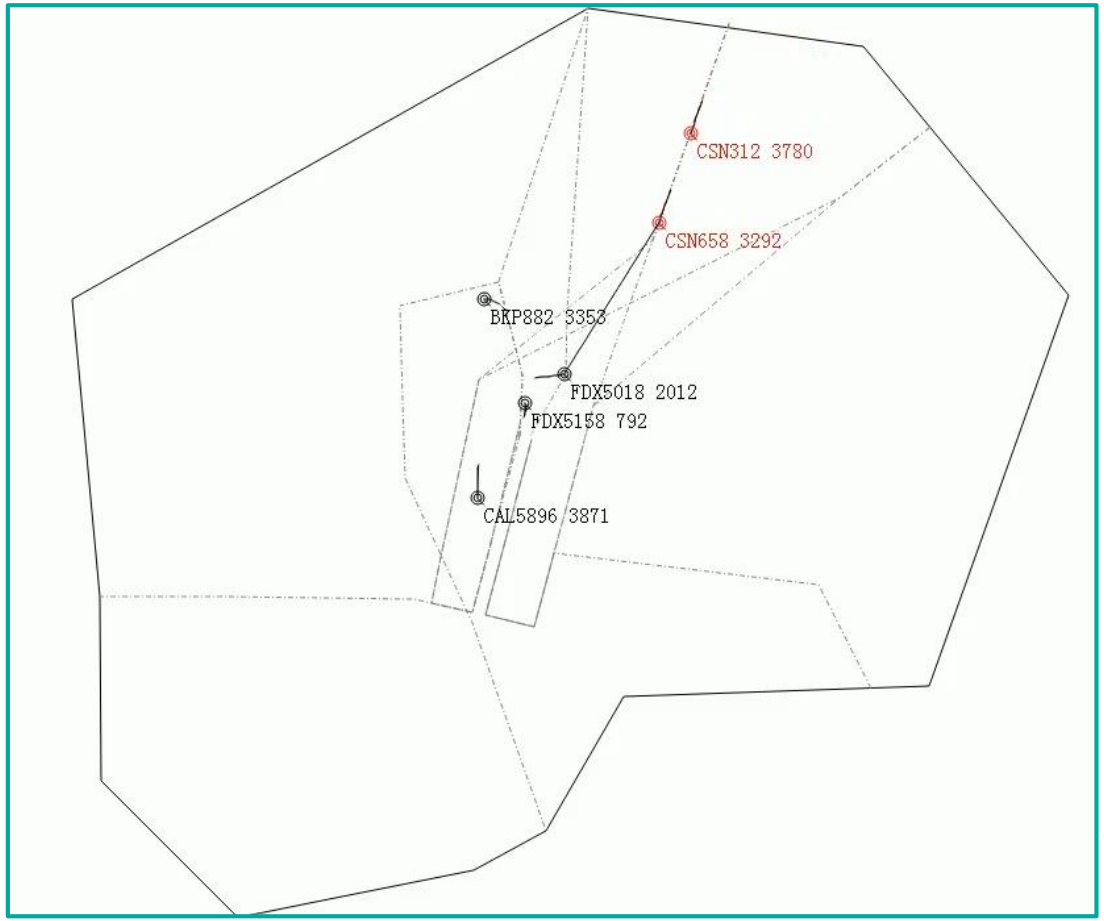

Evaluation for Procedure Operation

Methods and Results of Evaluation for CCO & CDO Operation

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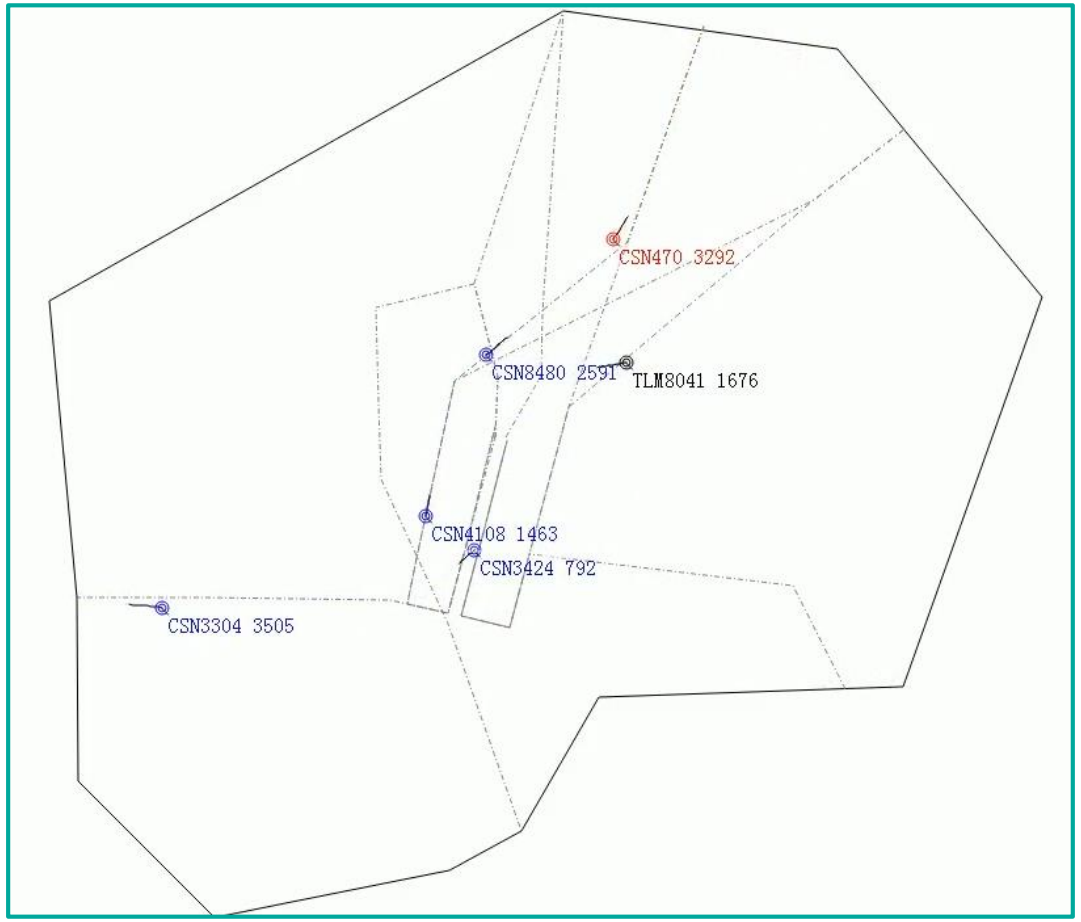
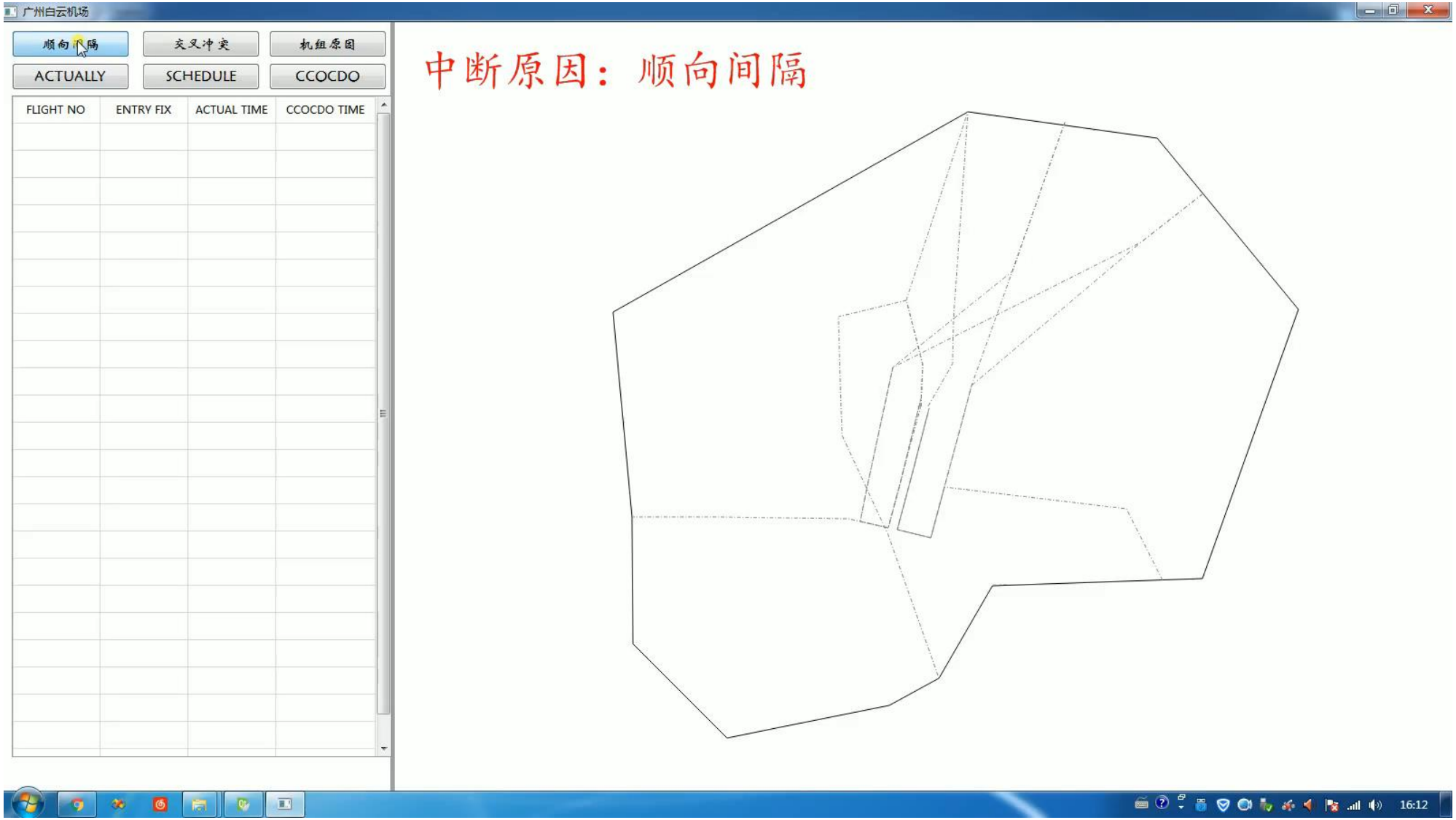
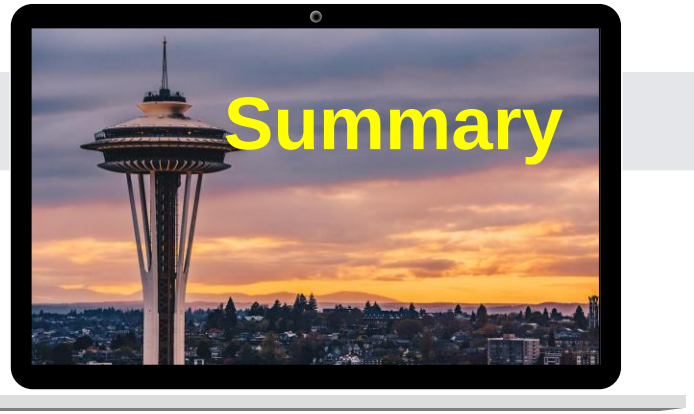


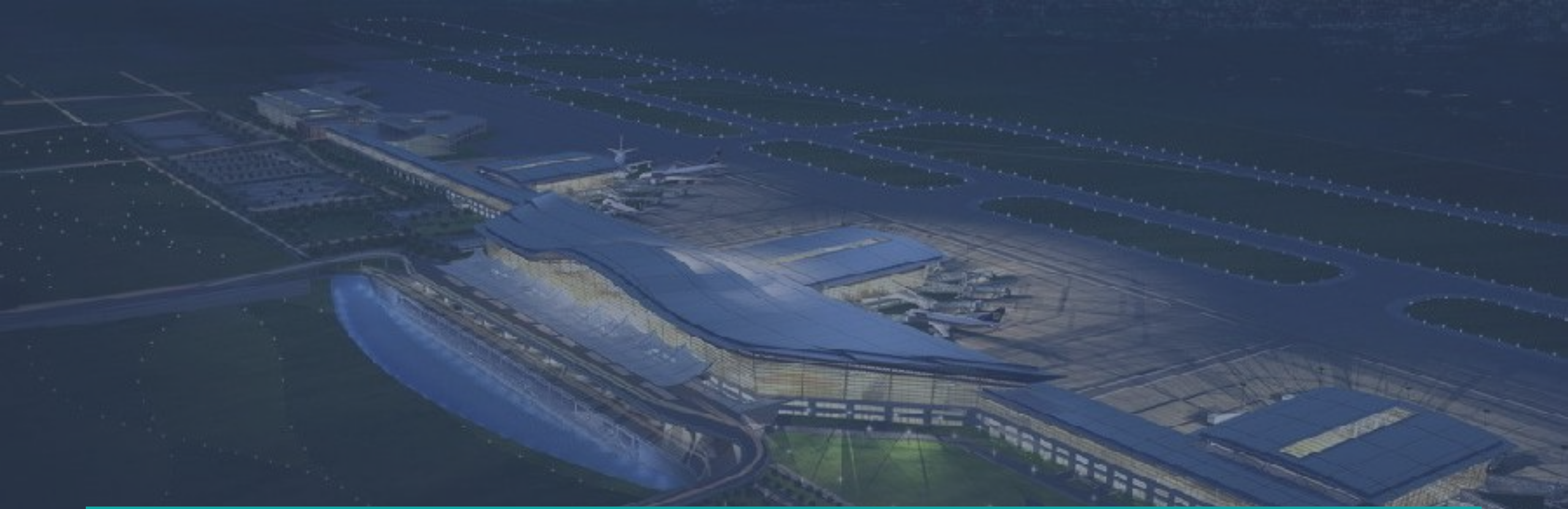
Evaluation for Procedure Operation





Flight Procedure Design, Validation, and operation

Multiple Evaluation	Aim & Focus	Data & Methods
Design	Vertical Profiles / Separation / Potential Benefits (to predict the Potential Issues that may be encountered in future)	Computer Simulation (Tool Developed by ourselves)
Validation	Where should be focused on / when to operate (workload of ATCOs)	Control Simulator
	How about the designed procedure / benefits / our tool	Flight Simulator
	Help all the stakeholders to be familiar with the CCO and CDO.	Test flight
Operation	Benefits and limitation; help to evaluate and modify our tool	QAR / Radar Tracks



Thanks! Any Questions?

zhangjunfeng@nuaa.edu.cn 13851944772 Junfeng ZHANG