



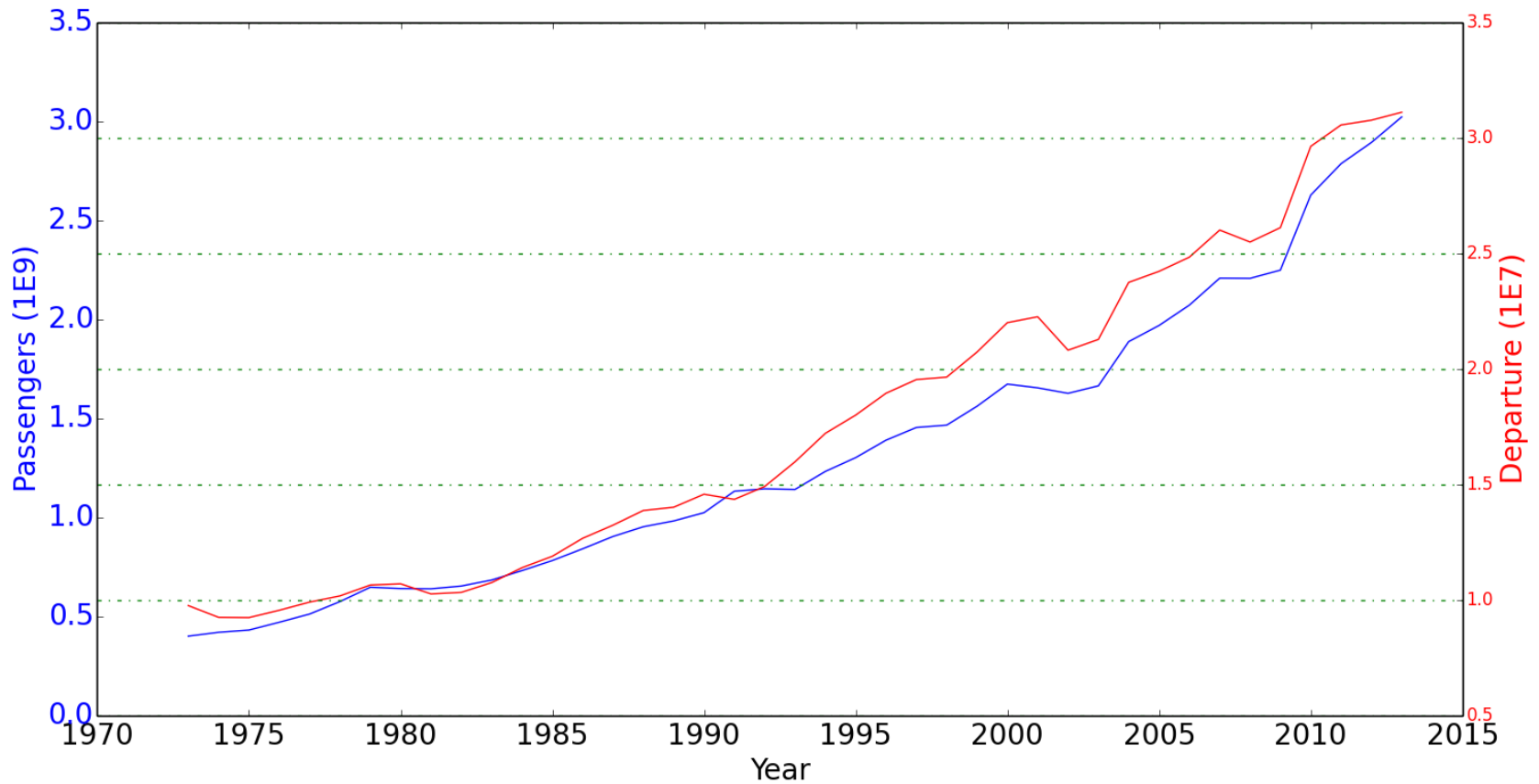
The evolution, challenges, and future of air traffic flow management



国家空管飞行流量管理技术重点实验室

Yanjun Wang and Hua Xie
National Key Laboratory of Air Traffic Flow Management
Nanjing University of Aeronautics and Astronautics
Email: ywang@nuaa.edu.cn

Traffic growth worldwide

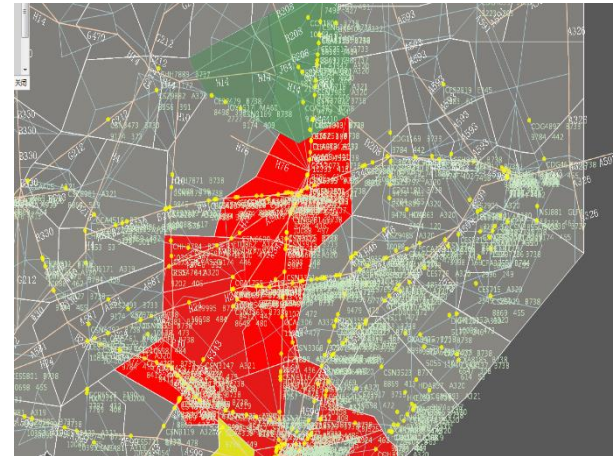


Data source: ICAO

Main problems



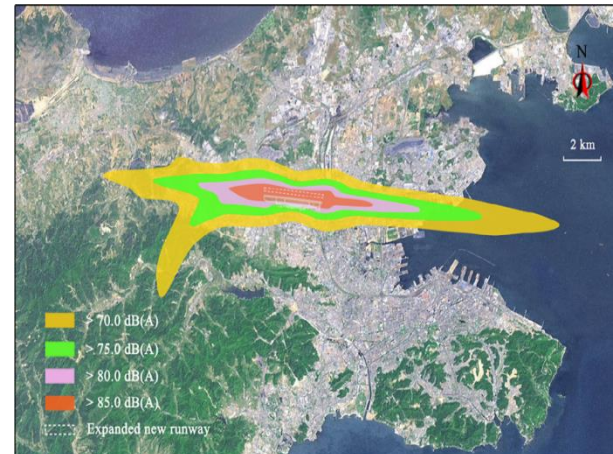
Delay



Congestion

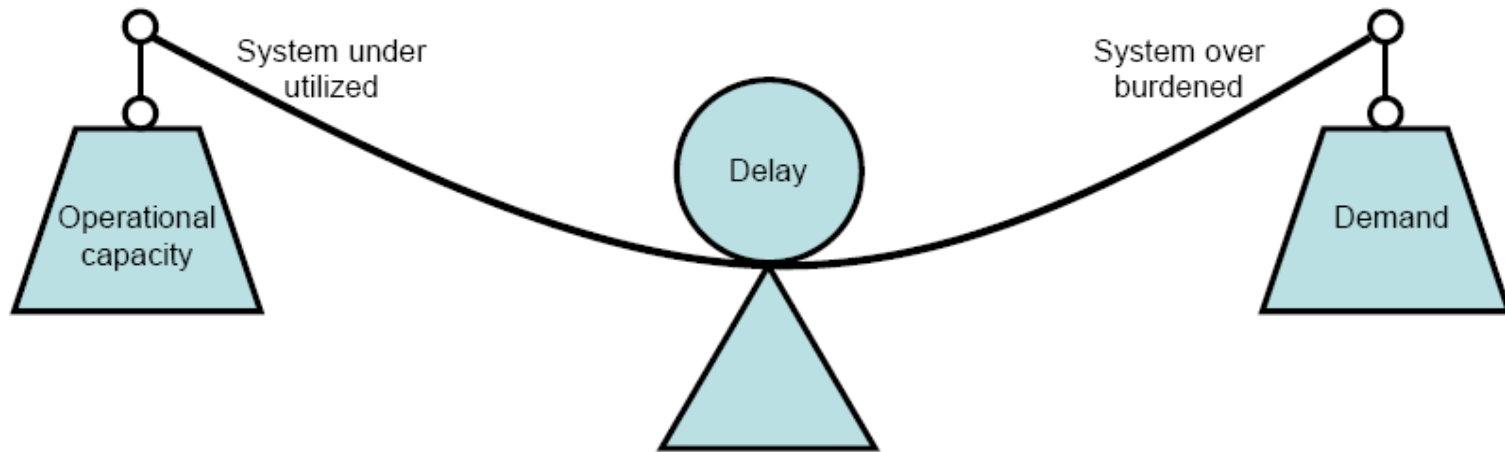


Safety and Security



Environmental Impacts

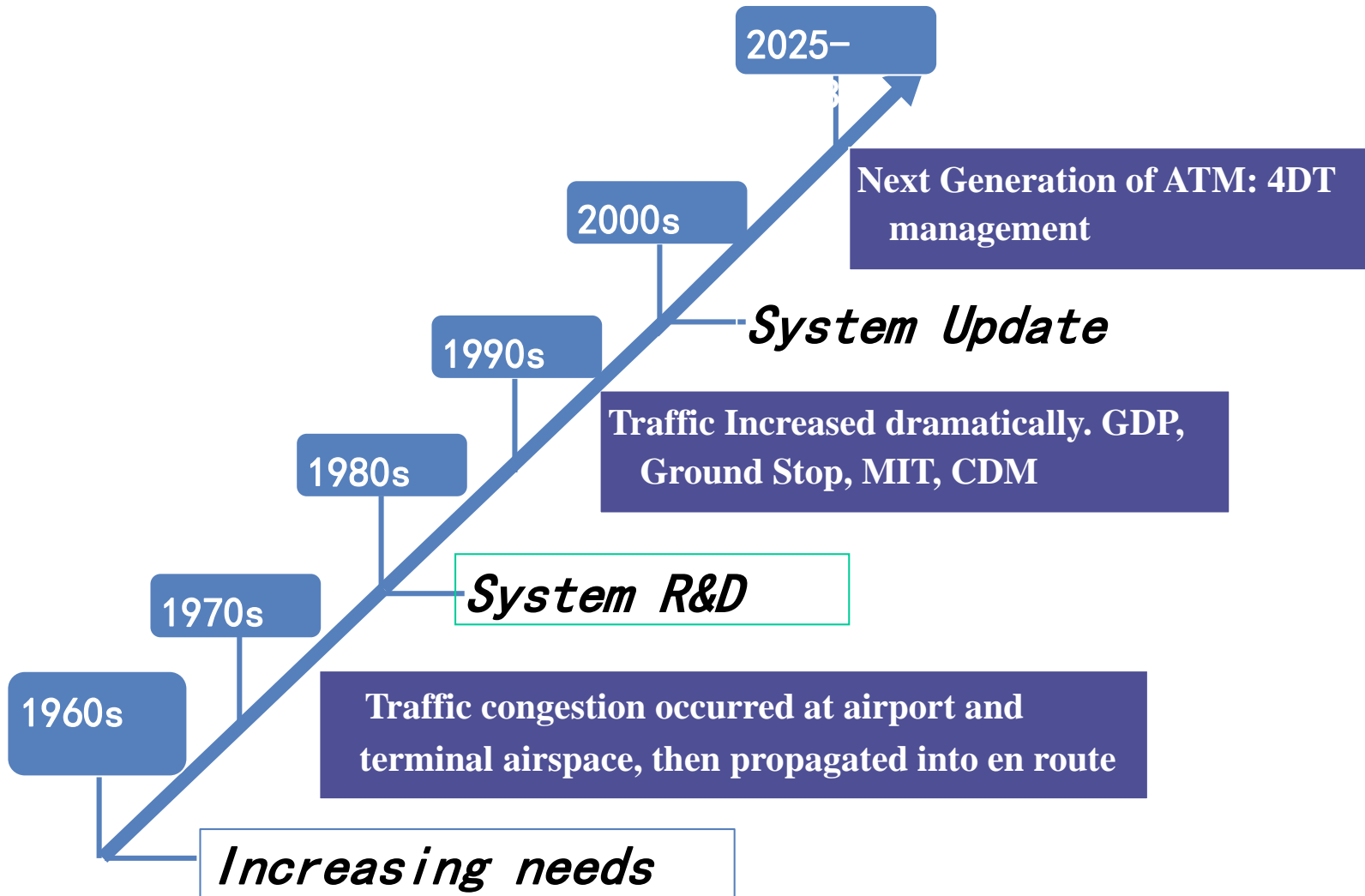
Demand-Capacity Balancing



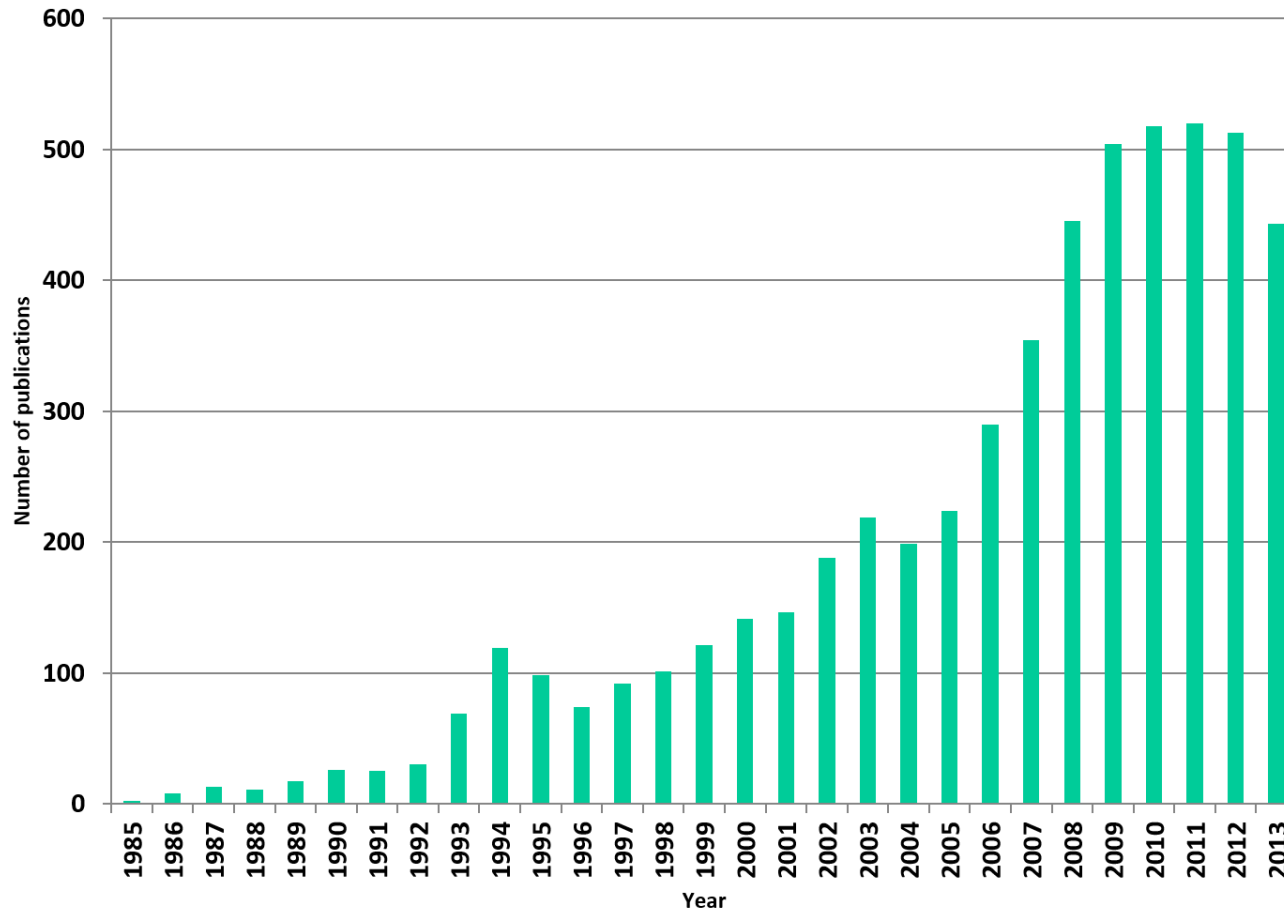
ATFM:

Safe, orderly and expeditious flow of air traffic by ensuring that ATC capacity is utilized to the maximum extent possible

Solution Before



Trend in ATFM research



The characteristics of ATM system

Uncertainty



...

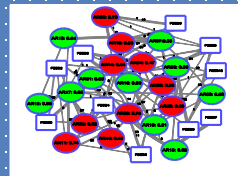
Diversity



	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday
08:00									
09:00									
10:00									
11:00									
12:00									
13:00									
14:00									
15:00									
16:00									
17:00									
18:00									
19:00									
20:00									
21:00									
22:00									
23:00									
24:00									

...

Complexity

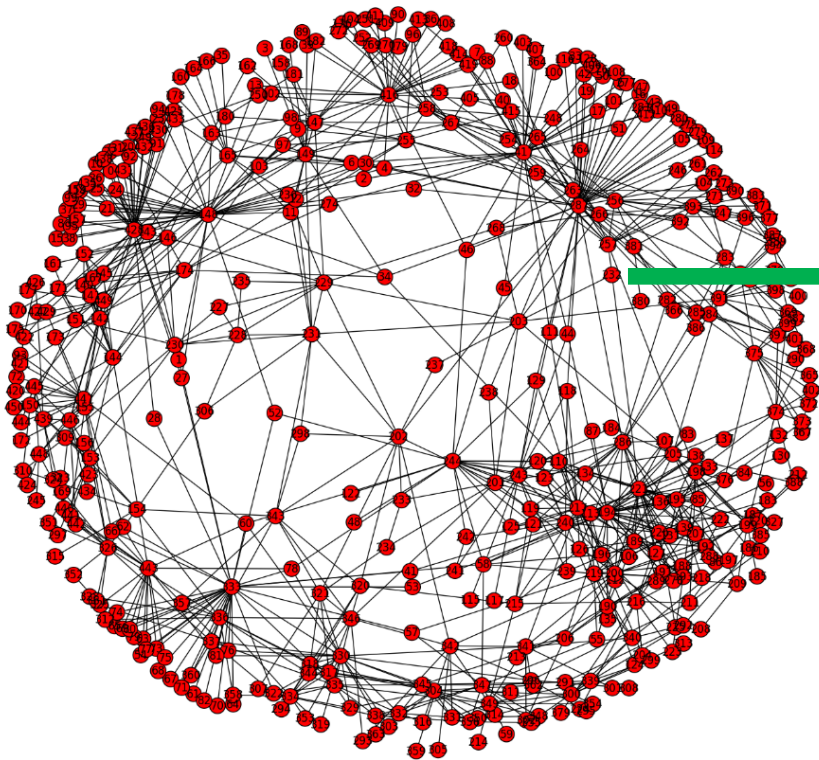


...

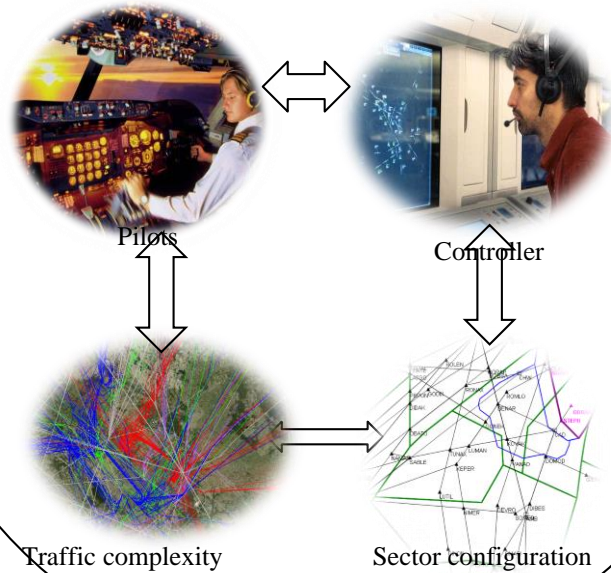
The characteristics of ATM system

	Primary Characteristics of Complex Systems	ATM System
1	Structural Complexity	✓
2	Behavioural Complexity	✓
3	Nested Complexity	✓
4	Evaluative Complexity	✓

ATM as a complex system



Nonlinear interaction in a sector



The network of Chinese ATM system

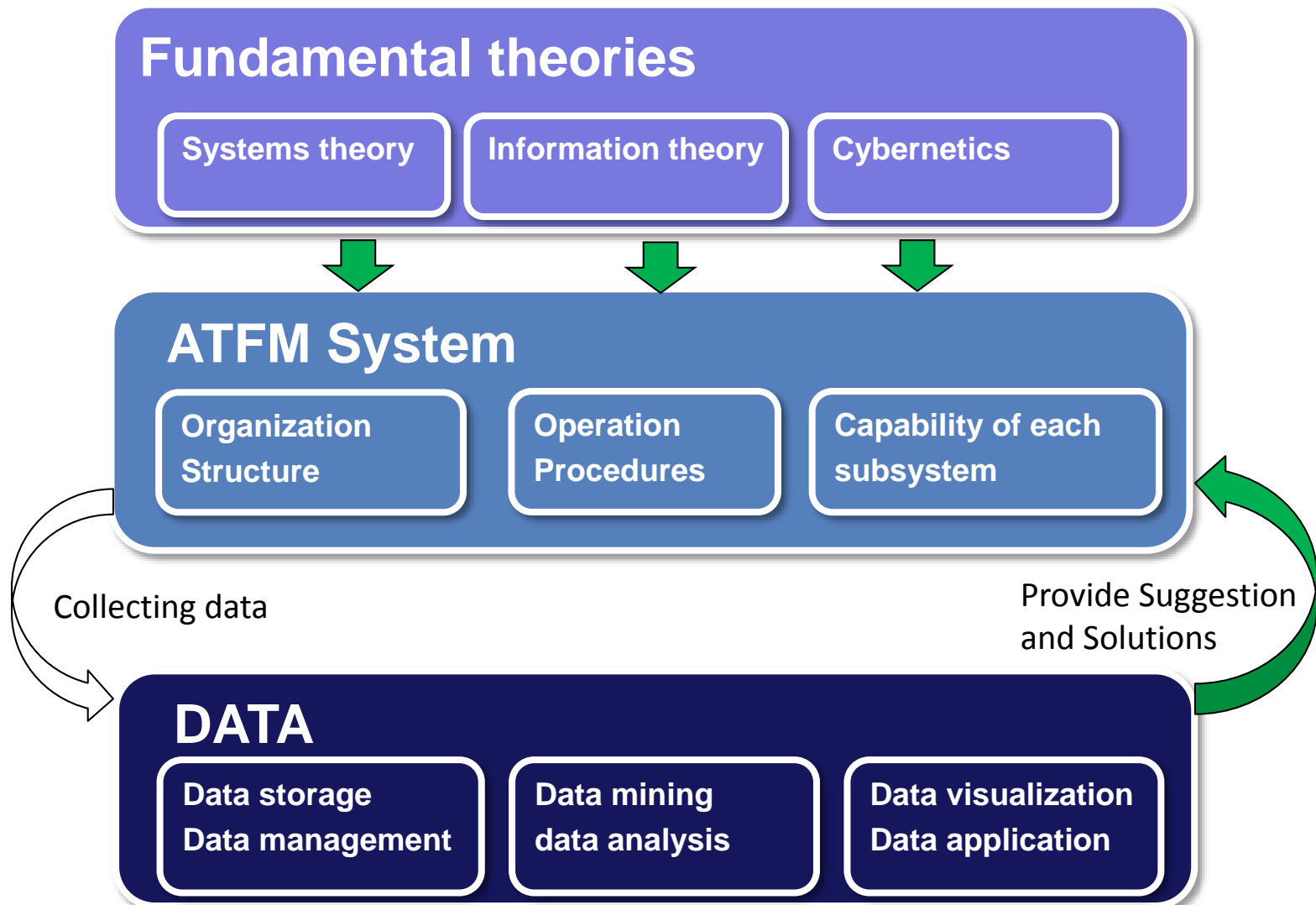
The ATFM problem becomes more and more complicated.....

how to solve it ? ? ?

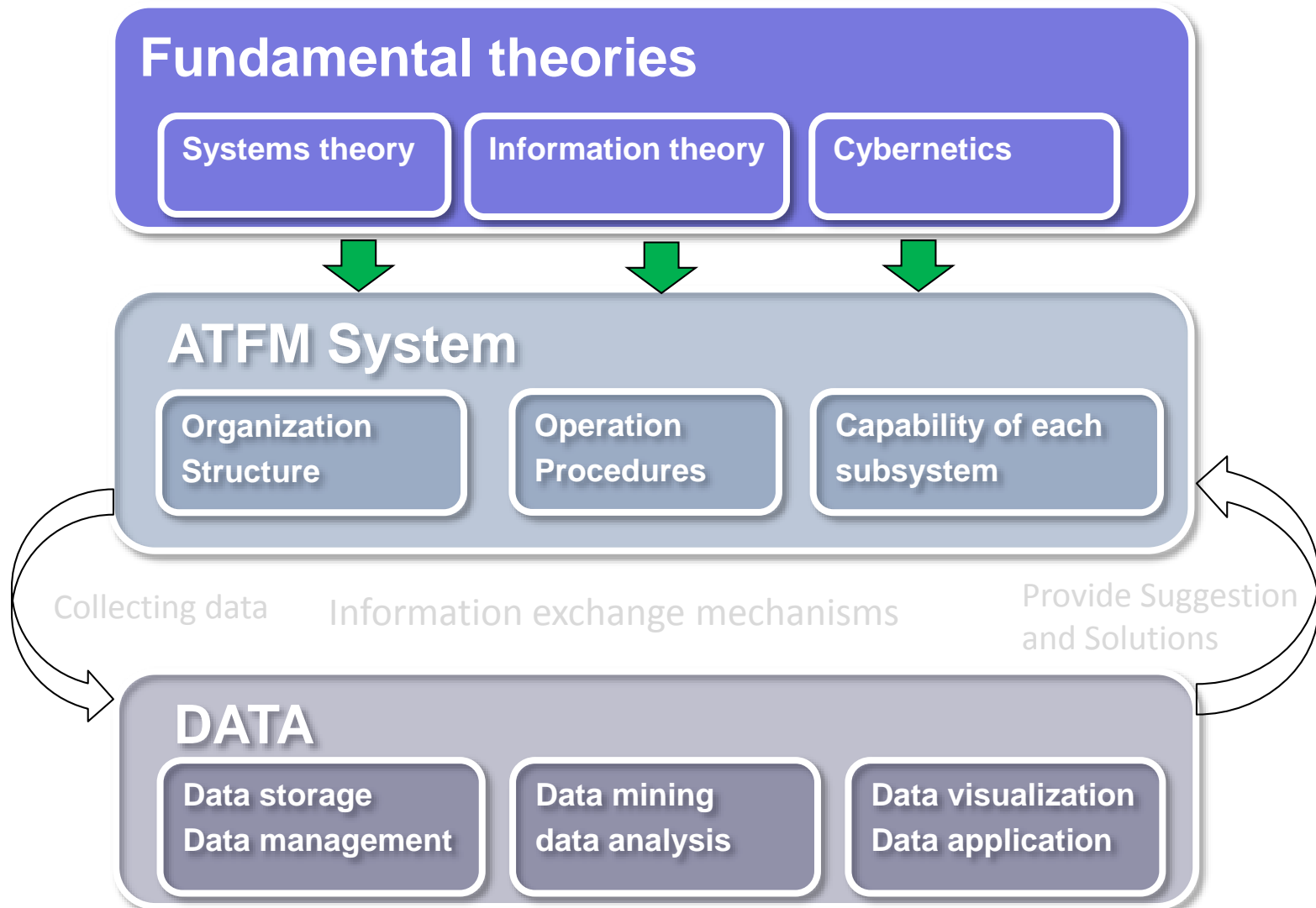
we need to consider.....



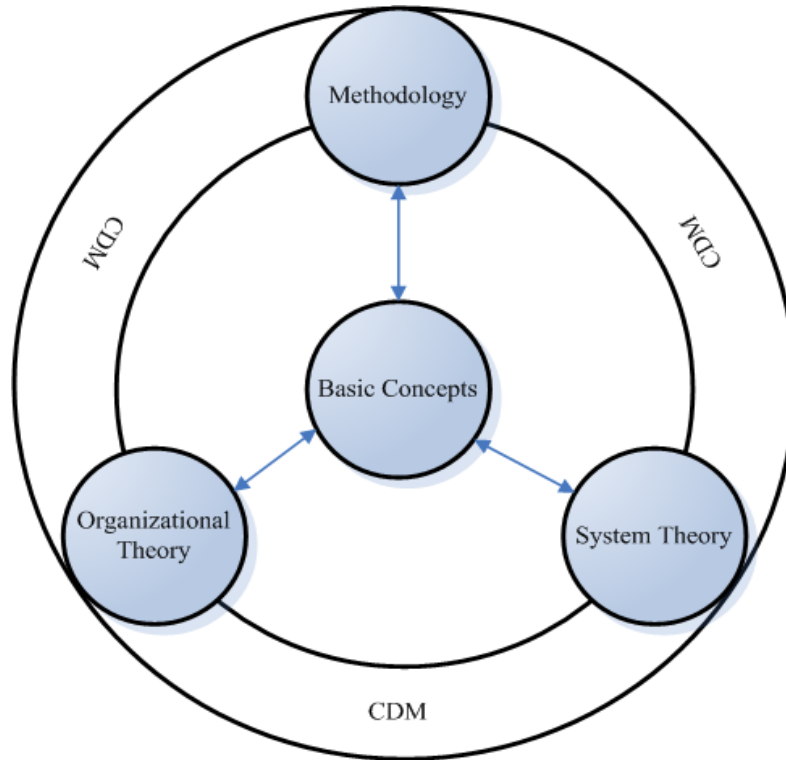
Key components of ATFM system



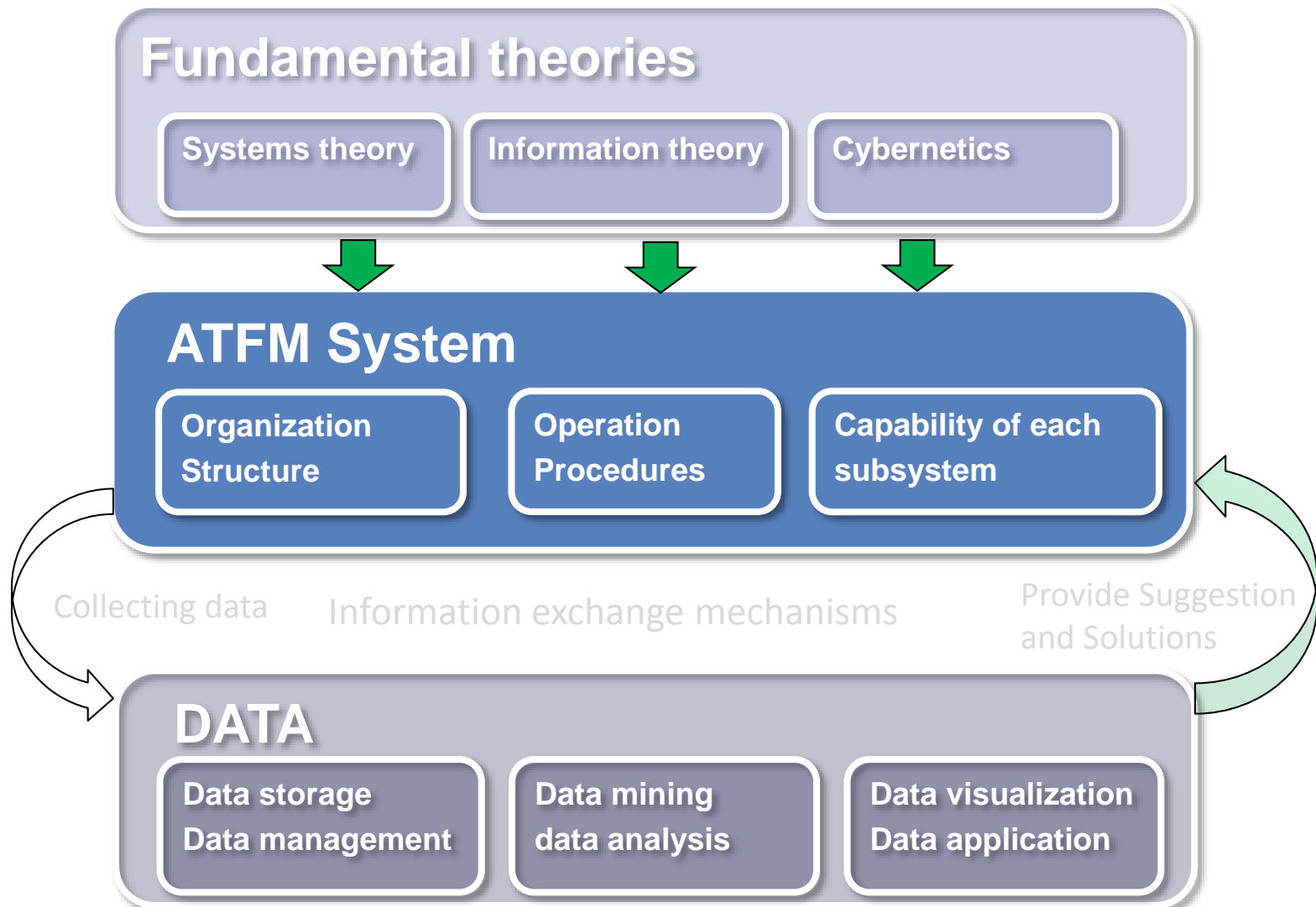
Key components of ATFM system



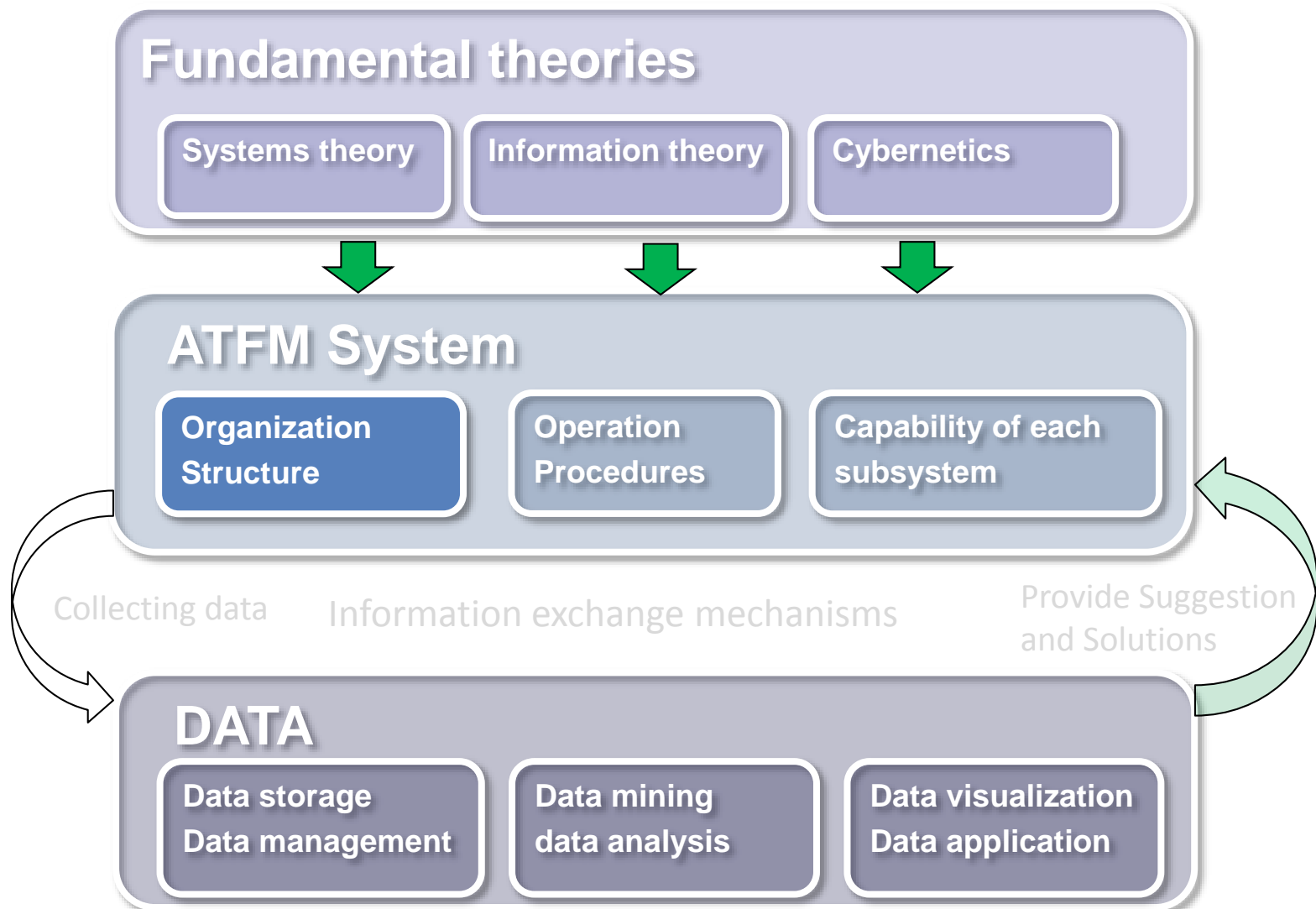
Theoretical model for ATFM



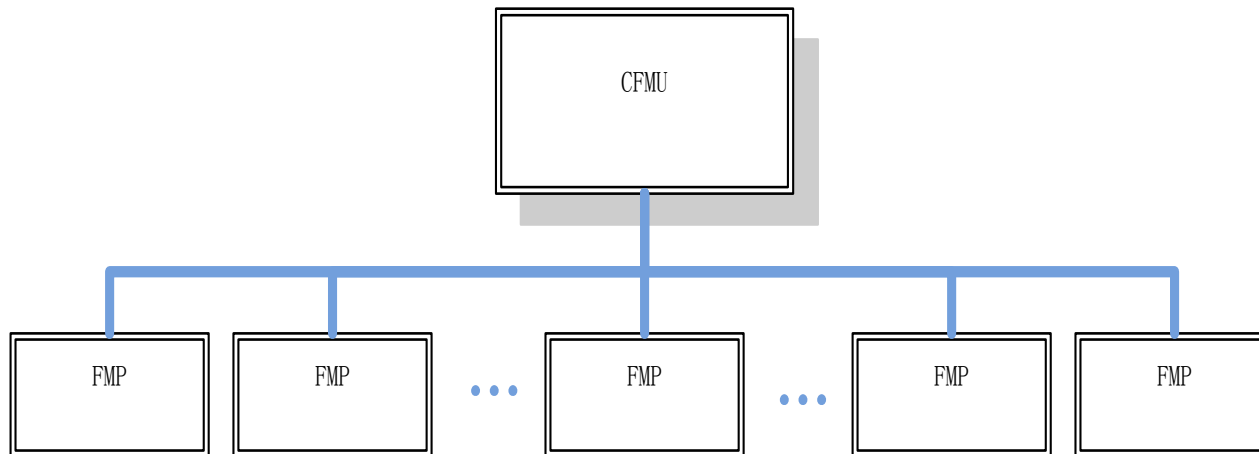
Key components of ATFM system



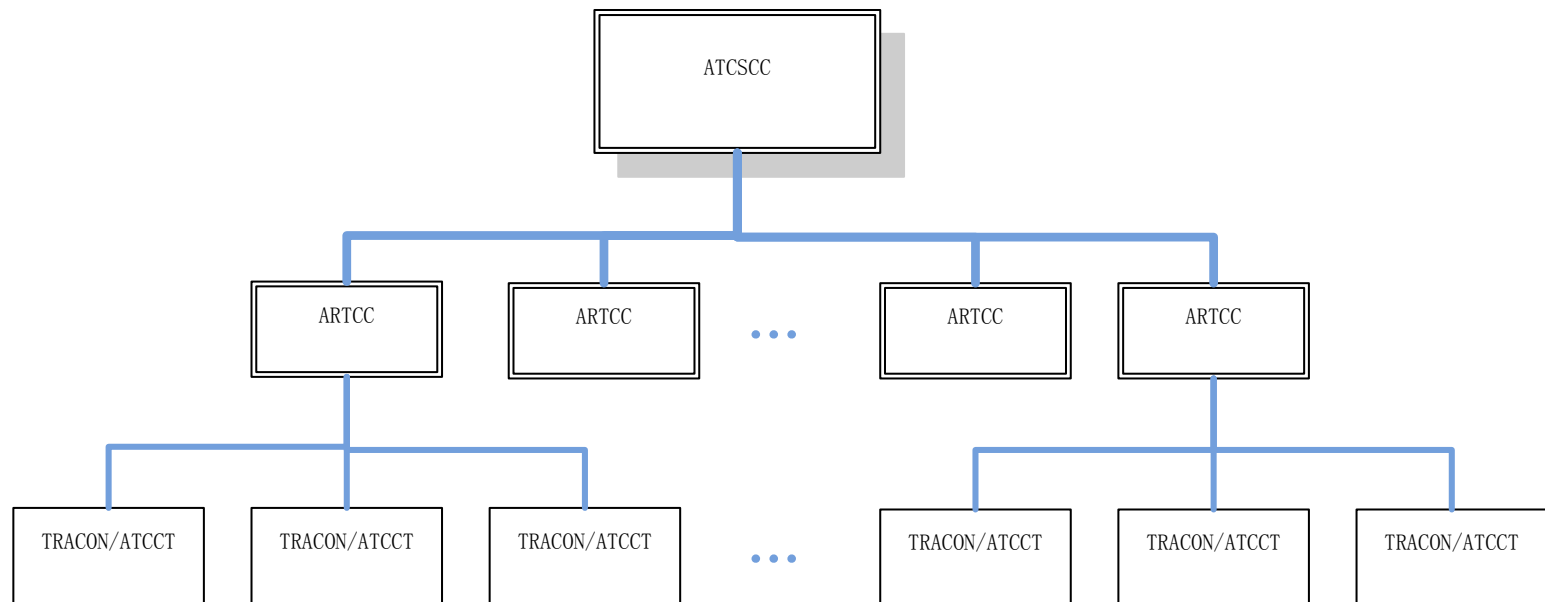
Key components of ATFM system



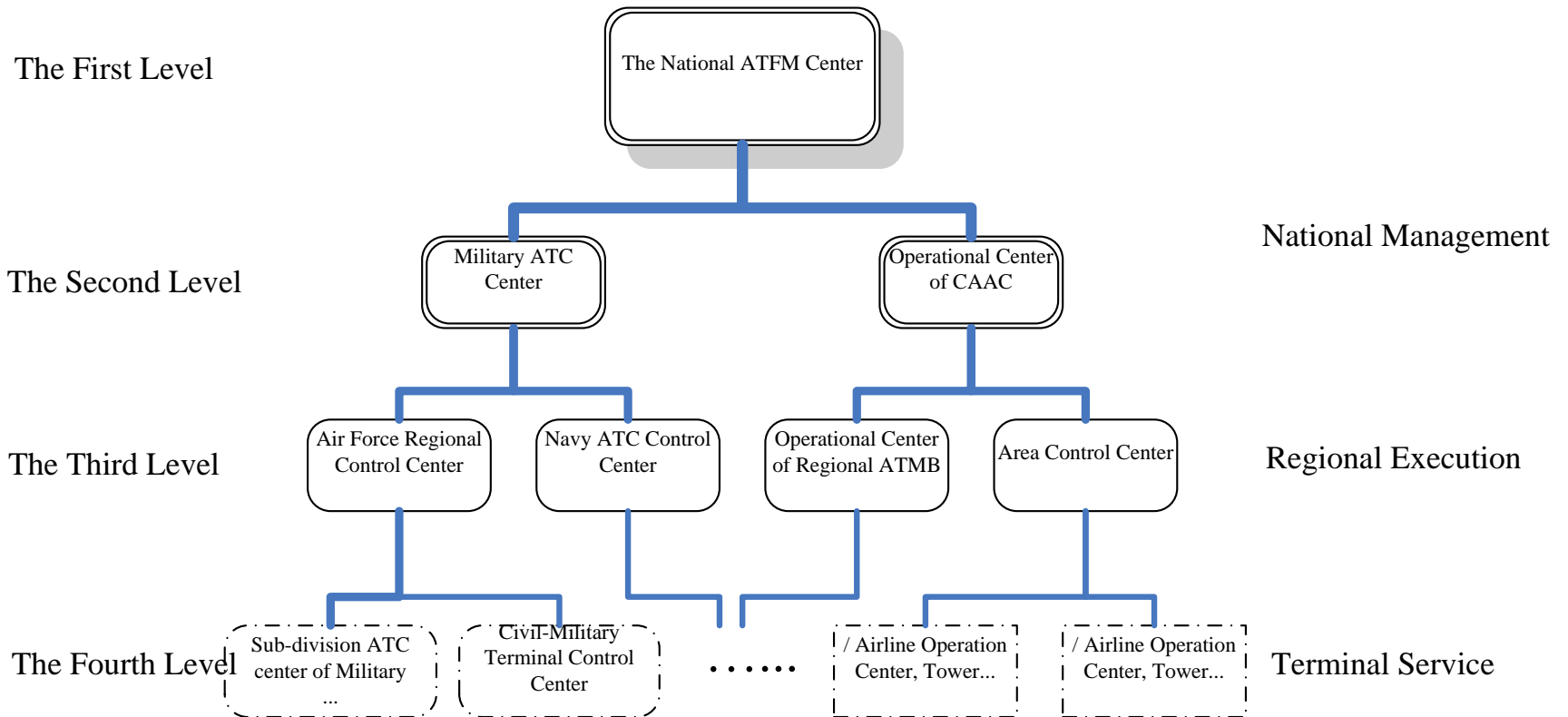
The structure of ATFM System in Europe



The structure of ATFM System in US

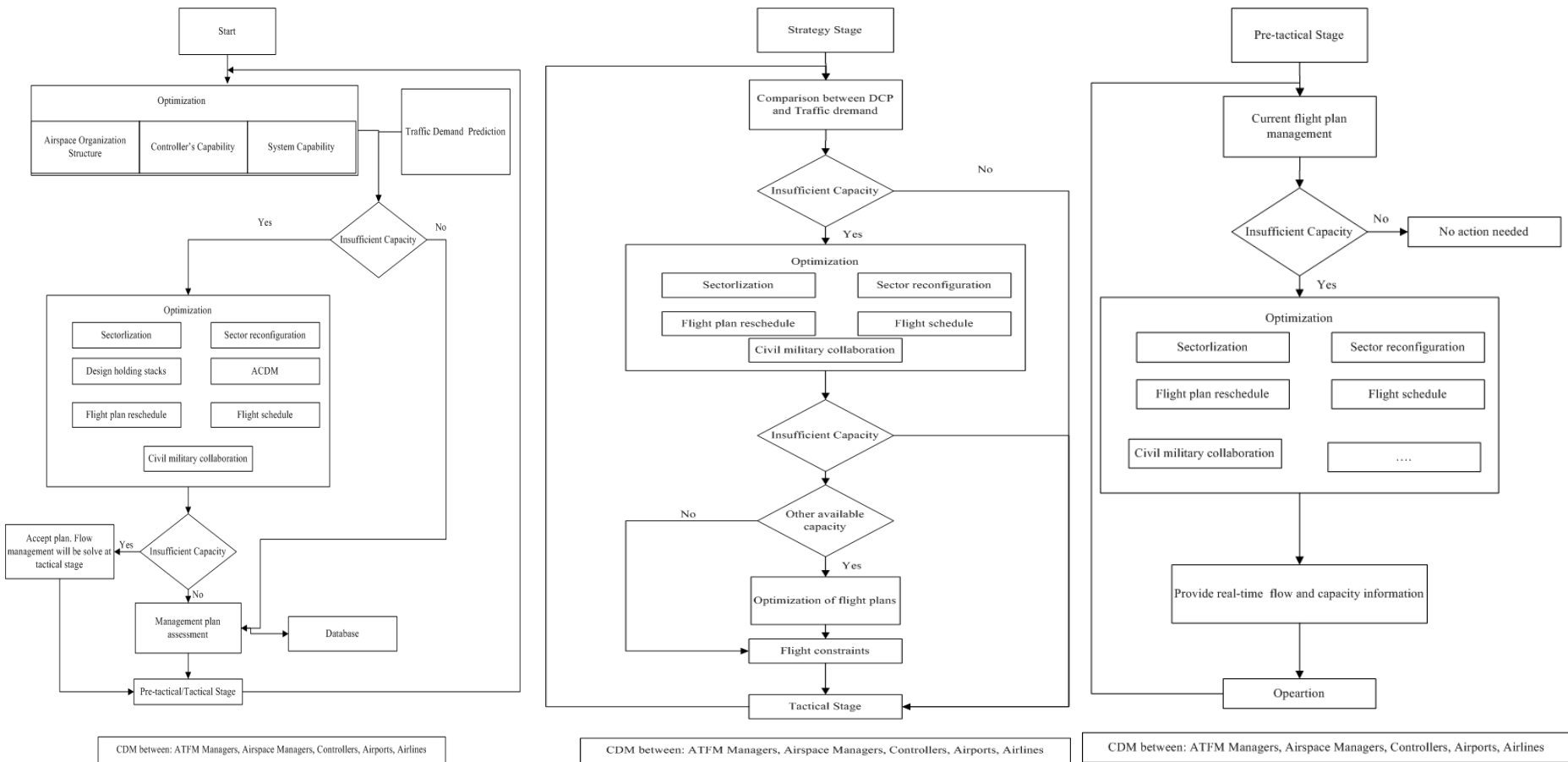


China ATFM organization



The Structure of ATFM System in China

Operation mechanisms



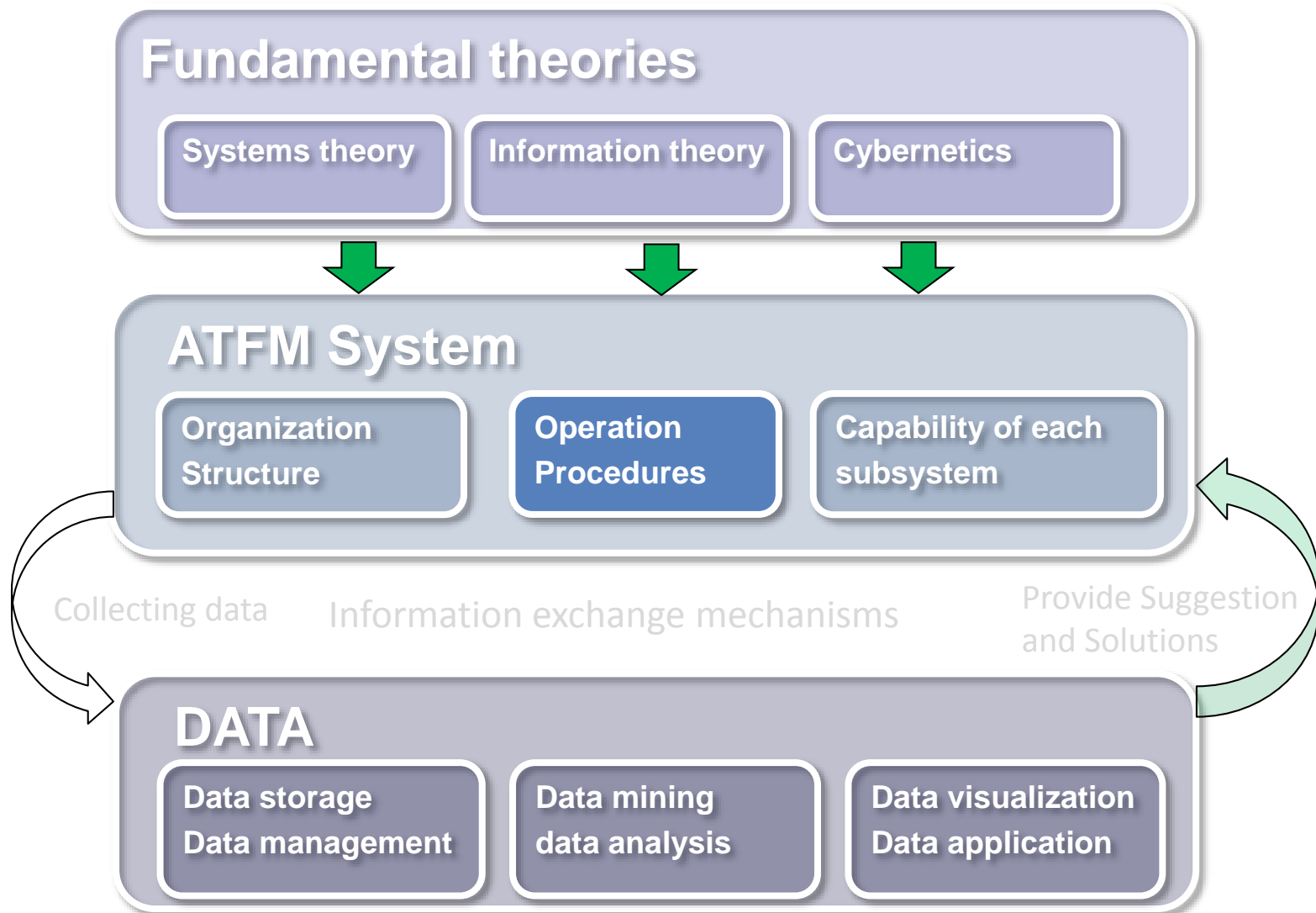
Strategic ATFM

Pre-tactical ATFM

Tactical ATFM

The Operation procedures of ATFM System in China

Key components of ATFM system

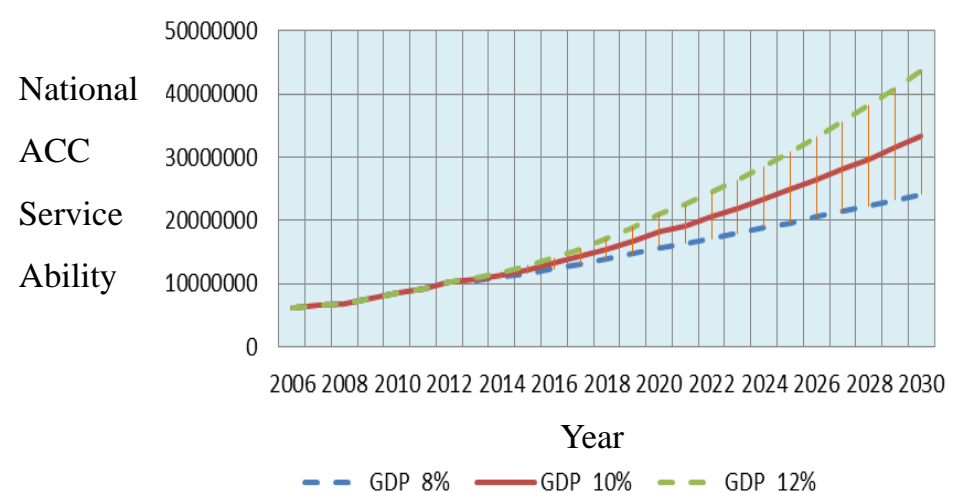
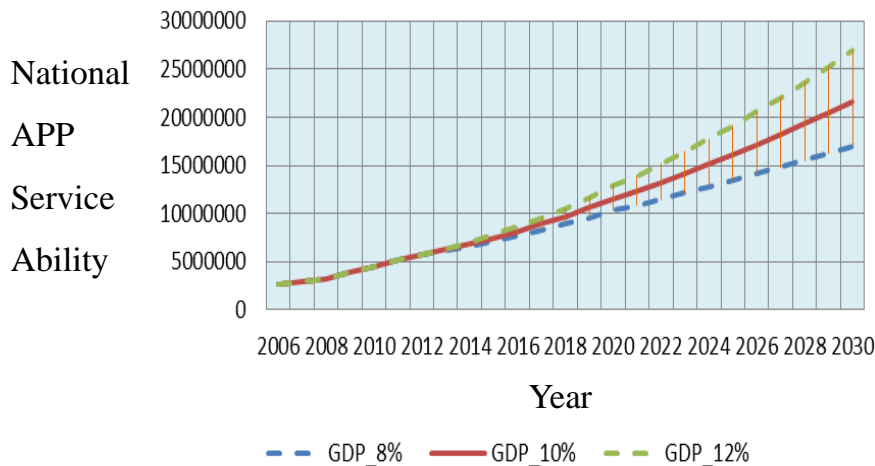
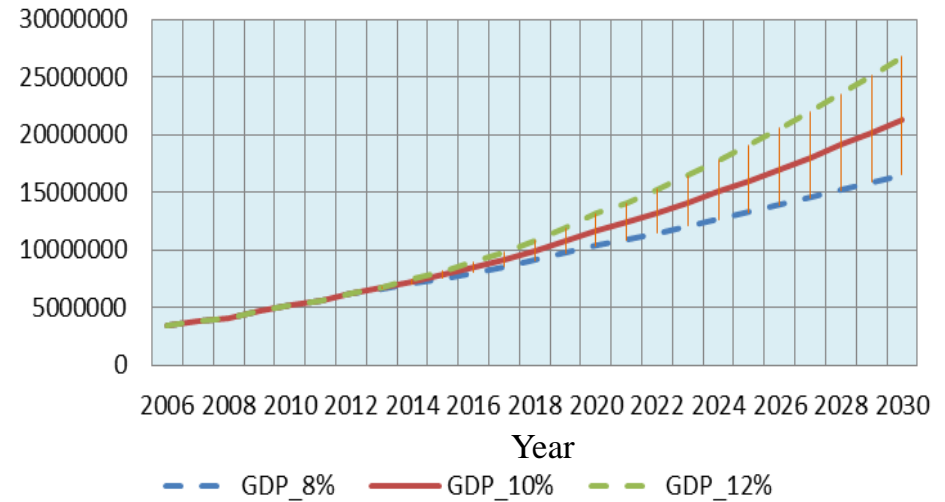


Operation procedures

❖ Operation procedures

- Demand Prediction
- Scheduling
- Airport Surface
- Arrival
- Departure
- En-route

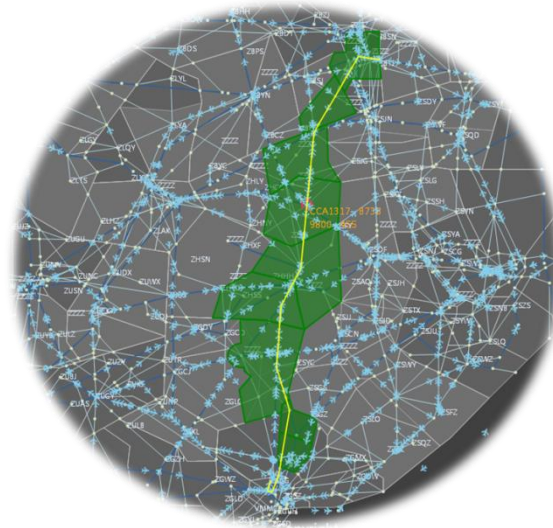
National
TWR
Service
Ability



Operation procedures

❖ Operation procedures

- Demand Prediction
- **Scheduling**
- Airport Surface
- Arrival
- Departure
- En-route



航班详细数据		航班号: CCA1328		飞机号: 10372481	
航空器状态:	CCA1328	航空器类型:	877W	起飞机场:	ZBAA
起飞机场:	ZGGG	降落机场:	ZBAA	计划起飞时间:	2012/9/13 19:10:00
计划起飞时间:	2012/9/13 19:10:00	计划到达时间:	2012/9/13 22:15:00	控制起飞时间:	2012/9/13 19:45:00
控制起飞时间:	2012/9/13 19:45:00	控制到达时间:	2012/9/13 22:03:00	实际起飞时间:	2012/9/13 19:45:00
实际起飞时间:	2012/9/13 19:45:00	实际到达时间:	2012/9/13 22:03:00	预计飞行总时间:	03:05:00
预计飞行总时间:	03:05:00	延误:			

过站序列	ZGGG	RWY20L	D5.01AA	FIX71	FIX72	FIX73	FIX74
过站属性	APT	APP	APP	APP	APP	APP	APP
过站时间	19:45	19:45	19:45	19:45	19:45	19:45	19:45
高度	0	1645.92	1679.61	1692.78	1702.83	1712.1	1715.82
速度	0	275.38	180	180	180	180	180

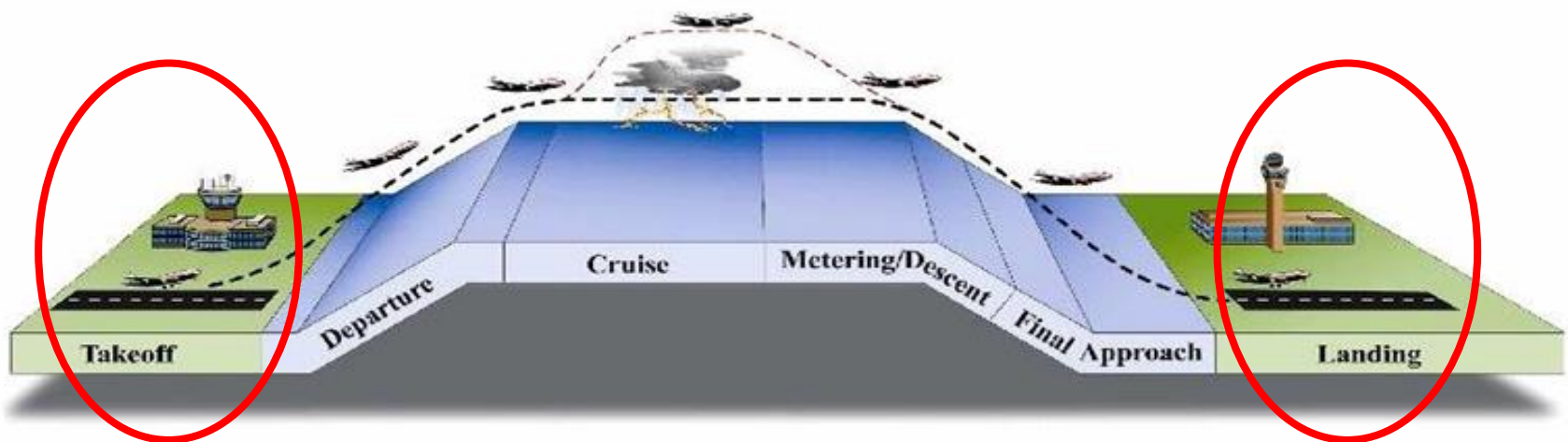
扇区名	ZGGGAP	ZGGGAR03	ZGGGAR13	ZGGGAR15	ZGGGAR16	ZHCCAR05	ZHCCAR03
进扇点名称	RWY20L	D20.0YINYN	BUBDA	DAPRO	ZF	OBLK	AKOMA
进扇时间	19:45	19:54	20:07	20:31	20:45	20:52	21:08
出扇点名称	D20.0YINYN	BUBDA	DAPRO	ZF	OBLK	AKOMA	WXI
出扇时间	19:54	20:07	20:31	20:45	20:52	21:08	21:19

Advanced Flight Schedule Manager

Operation procedures

❖ Operation procedures

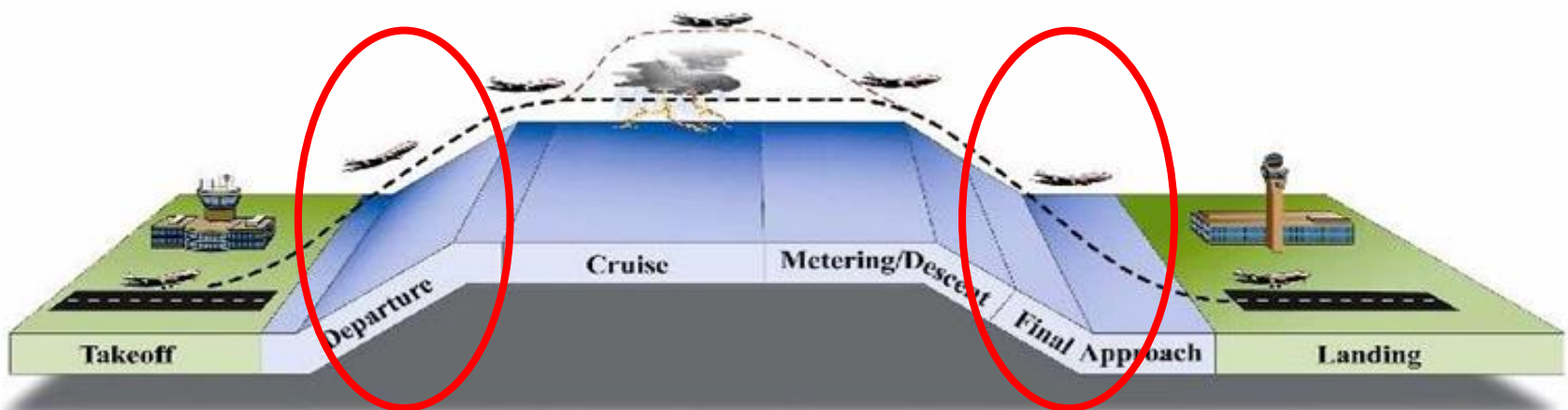
- Demand Prediction
- Scheduling
- **Airport Surface**
- **Arrival**
- **Departure**
- En-route



Operation procedure

❖ Operation procedures

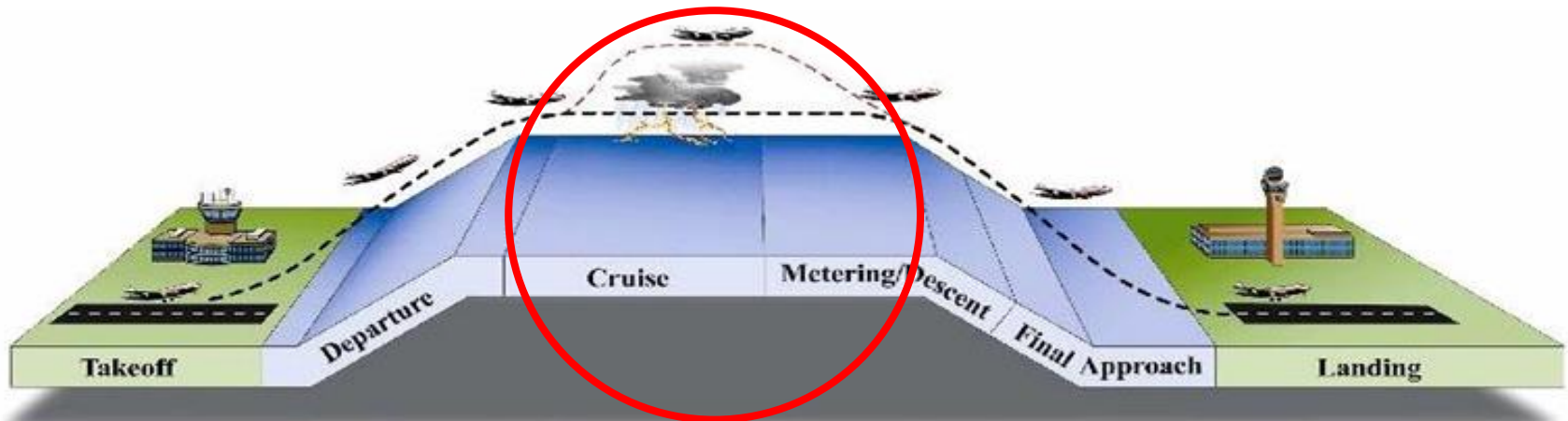
- Demand Prediction
- Scheduling
- Airport Surface
- **Arrival**
- **Departure**
- En-route



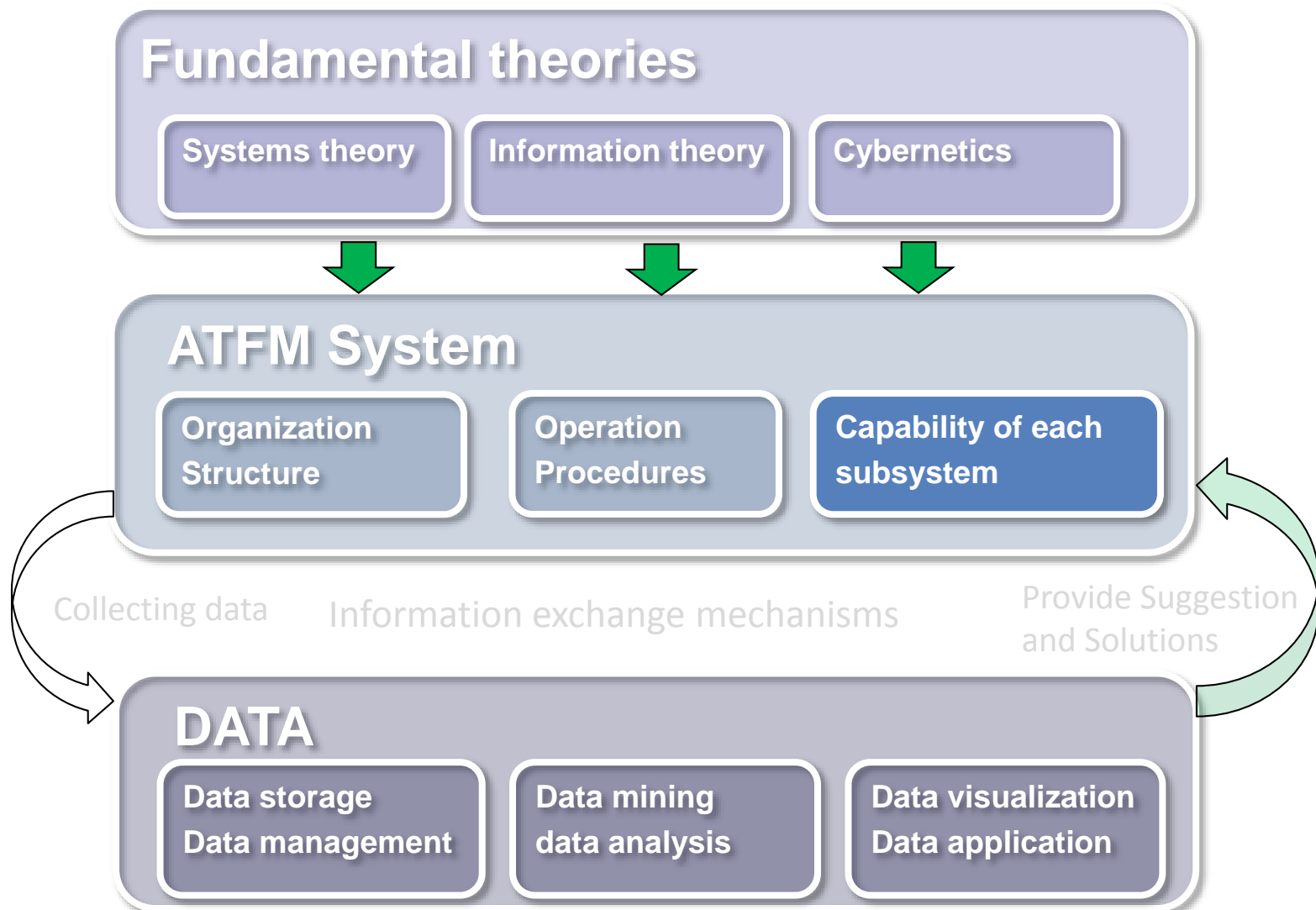
Operation procedures

❖ Operation procedures

- Demand Prediction
- Scheduling
- Airport Surface
- Arrival
- Departure
- **En-route**



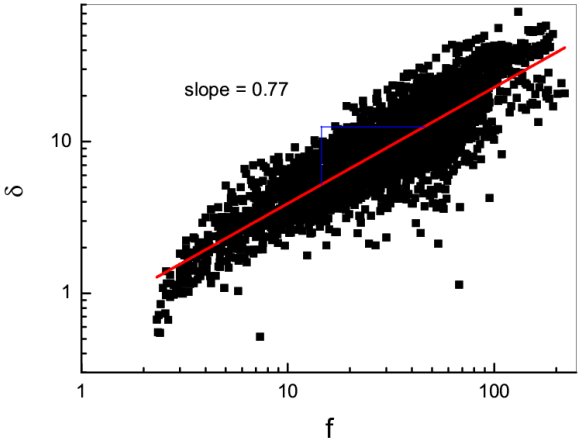
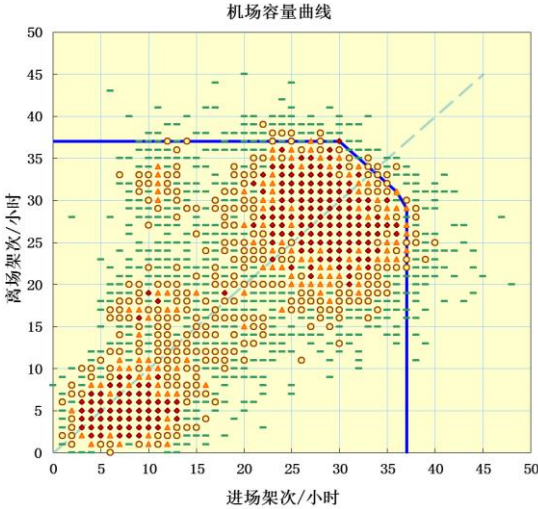
Key components of ATFM system



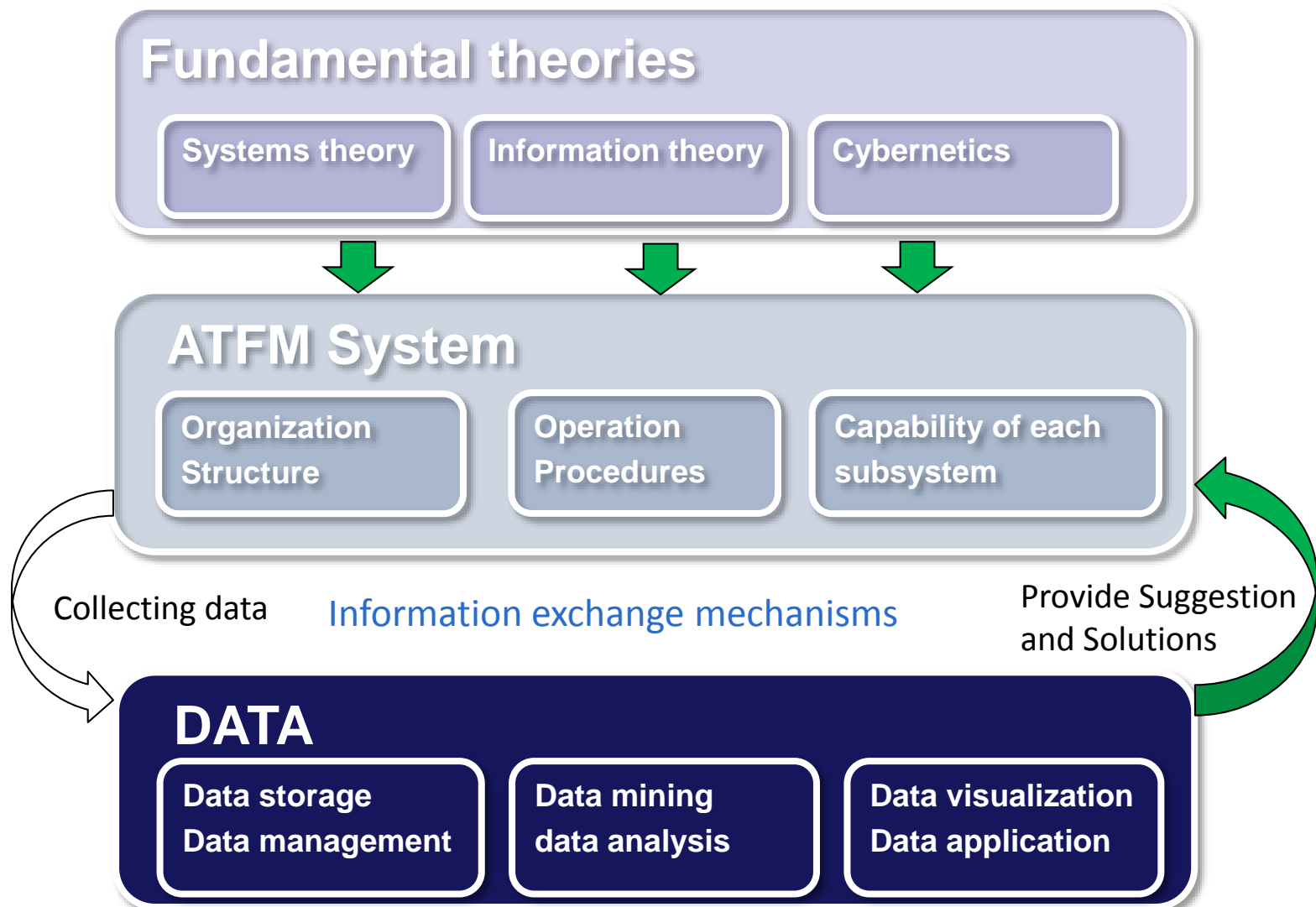
Capability assessment

❖ Capability Assessment

- Airports
- ATC
- Airlines
- Human
- System



Key components of ATFM system



Performance evaluation

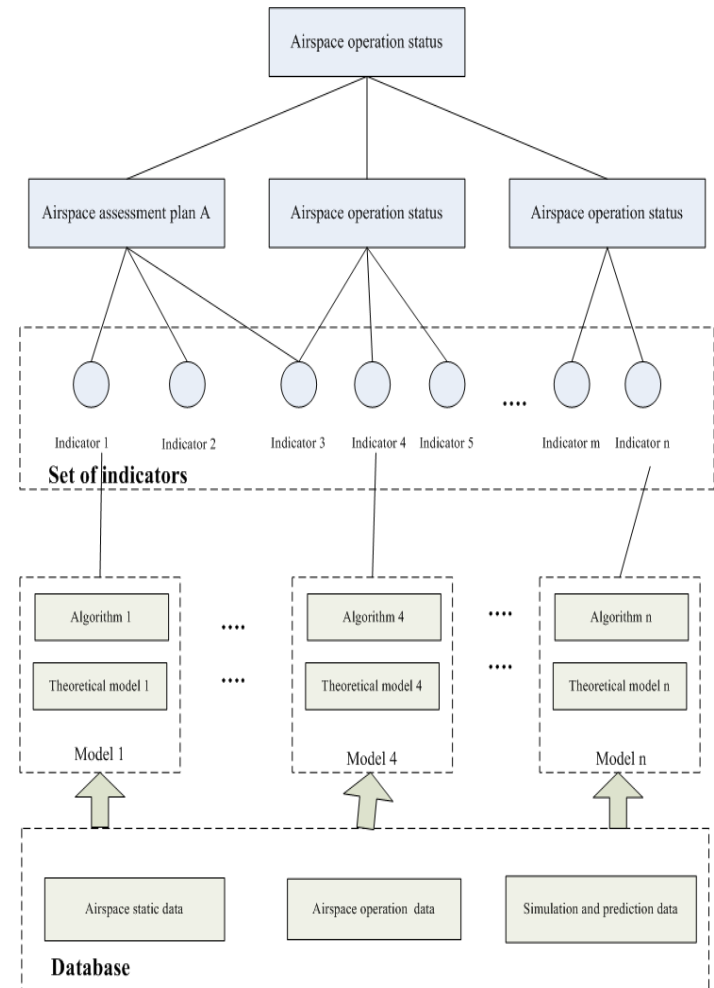
❖ Post-operation evaluation

➤ Indicator Scheme

- **Airspace Indicator**
- **Traffic Indicator**
- **Airport Indicator**
- **Airlines Indicator**

➤ Management Efficiency and Effectiveness

- **Organization Structure**
- **Operation Mechanisms**
- **Human Performance**



Systematic View

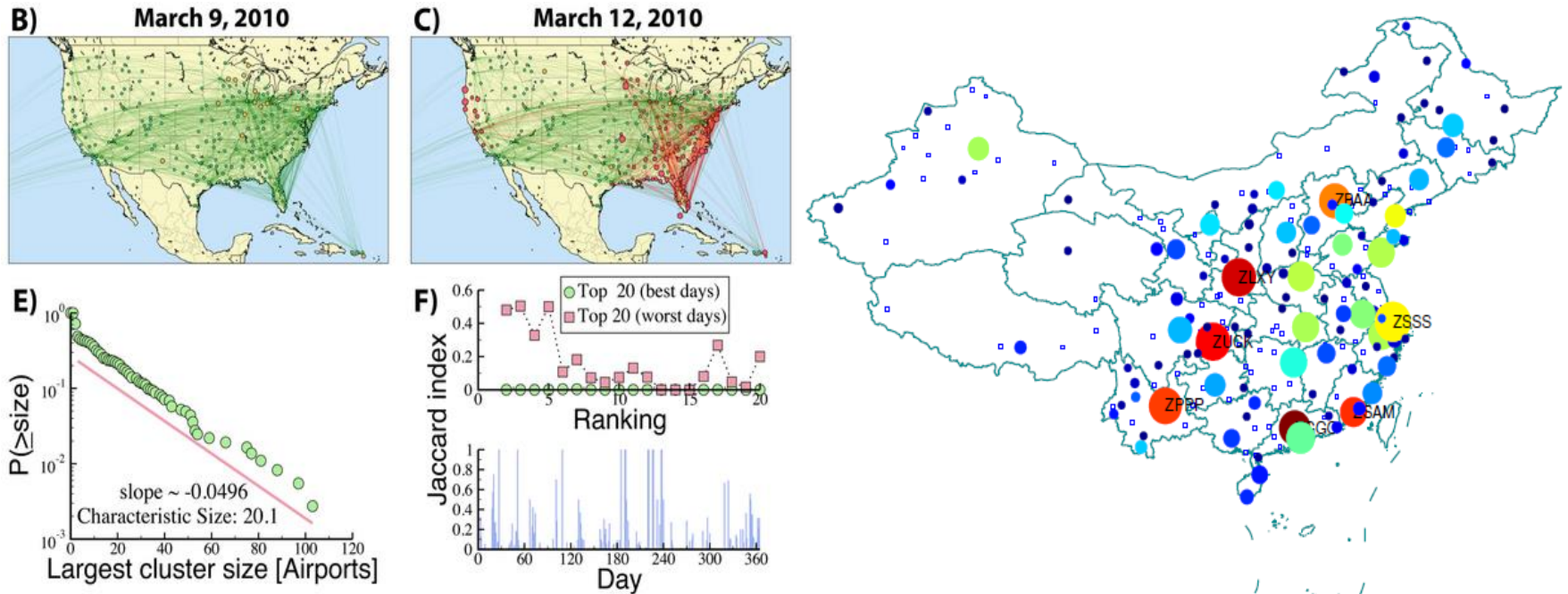


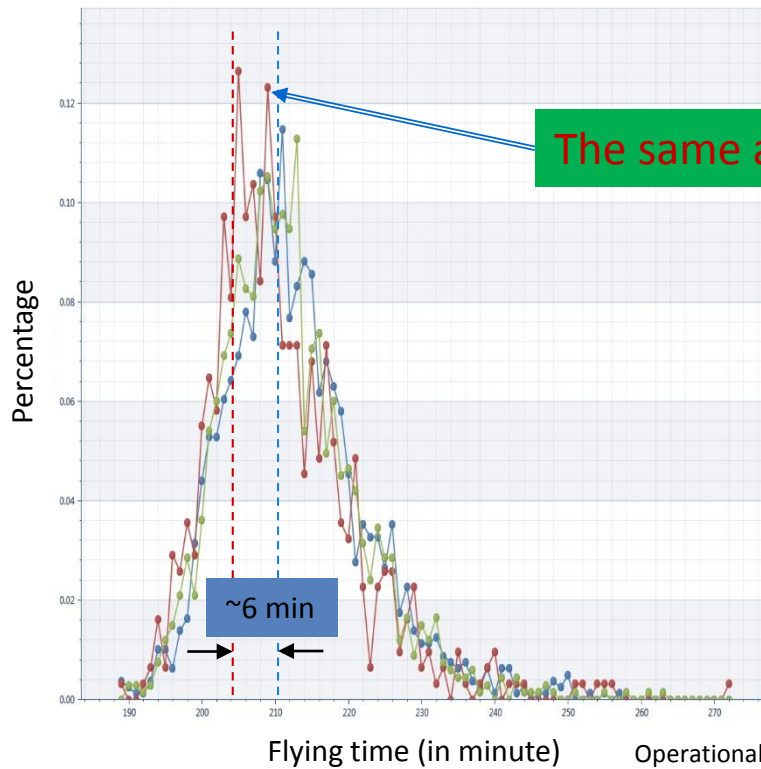
Figure courtesy of Fleurquin, P., Ramasco, J.J. & Eguiluz, V.M. Systemic delay propagation in the US airport network. *Sci. Rep.* 3, 1159; DOI:10.1038/srep01159 (2013).

Congested airport cluster

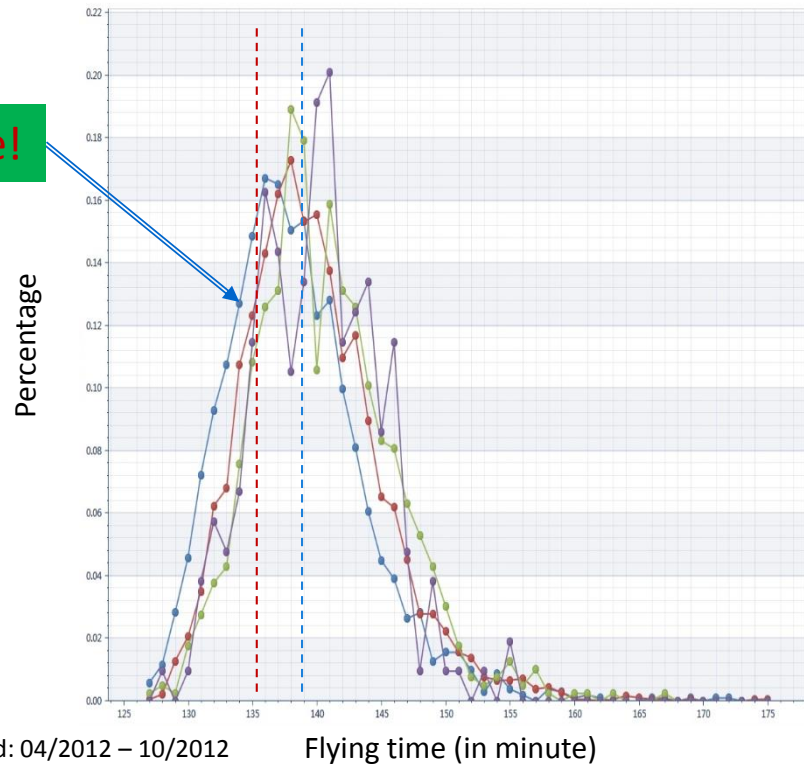
Delay propagation

Performance evaluation

Distributions of flying times (ZBAA to ZGSZ)



Distributions of flying times (ZBAA to ZSSS)



Airline behavior study based on data analysis

Information **T**echnology

Big data + Meaning = Information



Thank you !

