Enhancing Airspace Safety and Capacity using PBN
Bangkok TMA Case Study

Present by AEROTHAI

PBN Seminar and The Eighth Meeting of The Asia/Pacific PBN Task Force
9-13 May 2011, New Delhi, India

Topics

- **Analysis of Current Baseline Scenario**
  - Current SIDs/STARs and their Limitations
- **Agreement on Project Objectives and Scope**
  - Agreed Performance Criteria
- **Options to be evaluated**
  - Option 1: Open-STAR
  - Option 2: Point Merge
- **Performance Evaluation**
  - Capacity
  - Delay
  - Workload
  - Environment
- **Recommendations by ICAO and IATA**

Analysis of Baseline Scenario

Assessment of CNS/ATM Infrastructure for Bangkok TMA

Communication

- 100% VHF Direct-Voice Communication

Surveillance

- 100% Radar-coverage
  - PSR, SSR at both Suvarnabhumi and Don Mueang
  - Surface Movement RADAR and Multilateration at Suvarnabhumi
  - ADS-B implementation is on-going

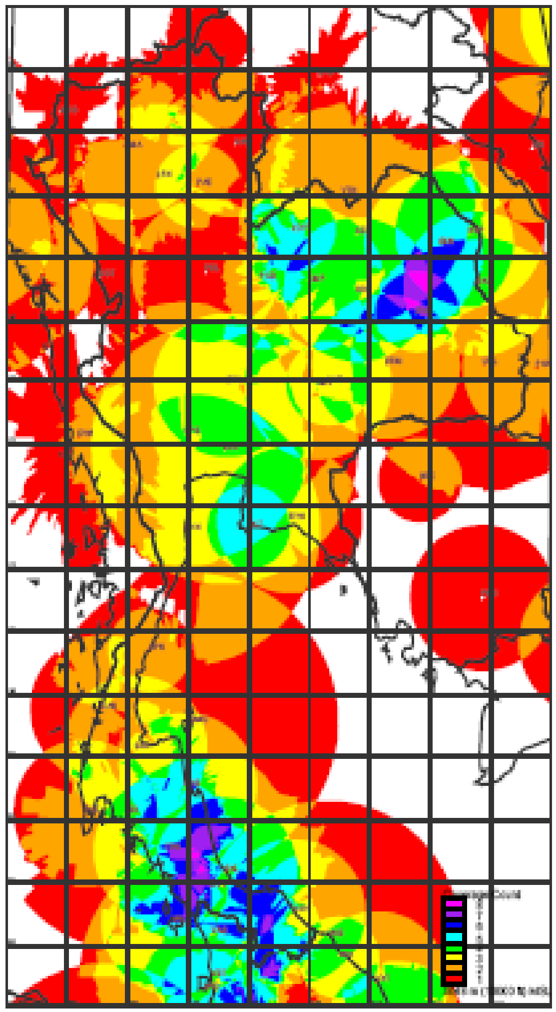
ATM System

- Eurocat X
- Maestro available

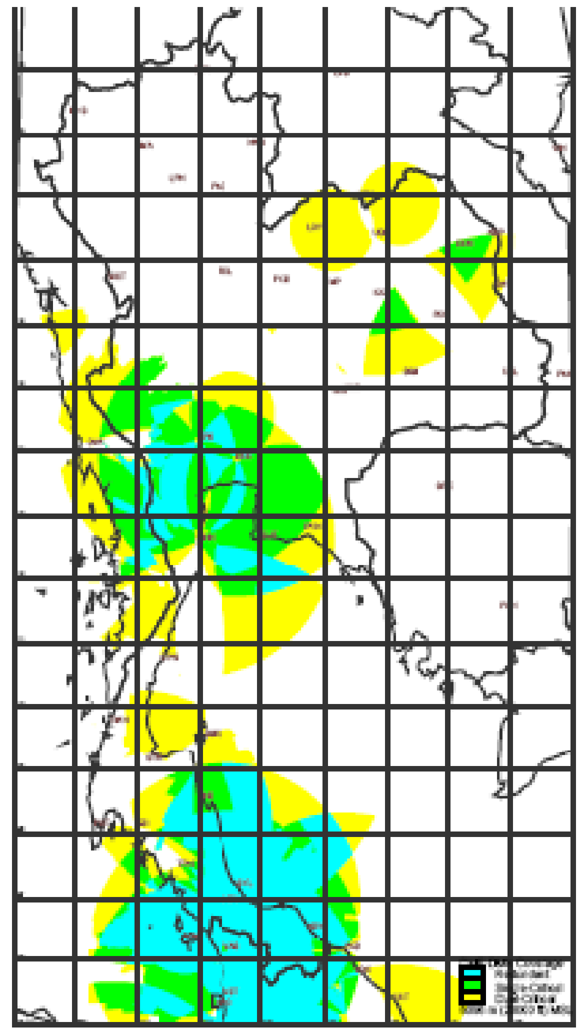
Navigation

- VOR/DME and 4xILS/DME available for Suvarnahumi
- VOR/DME and 3xILS/DME available
- 100% VOR/DME and DME/DME Coverage
- GNSS performance and interference are well-tested and being monitored in real-time.

Assessment of CNS/ATM Infrastructure for Bangkok TMA



VOR/DME - 10,000 ft



DME/DME - 10,000 ft

Assessment of Fleet Capability at VTBS

Aircraft Type (Departure)		%
A320	WTC M	16.42
B744	WTC H	9.28
A333	WTC H	9.36
A306	WTC H	9.31
B772	WTC H	7.37
A319	WTC M	5.95
B733	WTC M	4.74
AT72	WTC M	5.30
B734	WTC M	4.73
B773	WTC H	4.09
Others		23.45

Aircraft Type (Arrival)		%
A320	WTC M	16.14
B744	WTC H	9.27
A333	WTC H	9.20
A306	WTC H	9.28
B772	WTC H	7.39
A319	WTC M	5.84
B733	WTC M	4.74
AT72	WTC M	5.35
B734	WTC M	5.03
B773	WTC H	4.08
Others		23.69

Assessment of Fleet Capability at VTBS

STAR and SID

- Almost all aircraft capable of RNAV-1
- Operate pre-PBN RNAV(GNSS) SID/STAR since the beginning of airport operation in 2008.

Approach

- About 70% of aircraft capable of RNP APCH with or w/o Baro-VNAV
- RNP APCH w/ Baro-VNAV can be designed to provide back-up to ILS

- Similar case for VTBD

Assessment of MET Conditions

- Tropical Rain
- Some fog

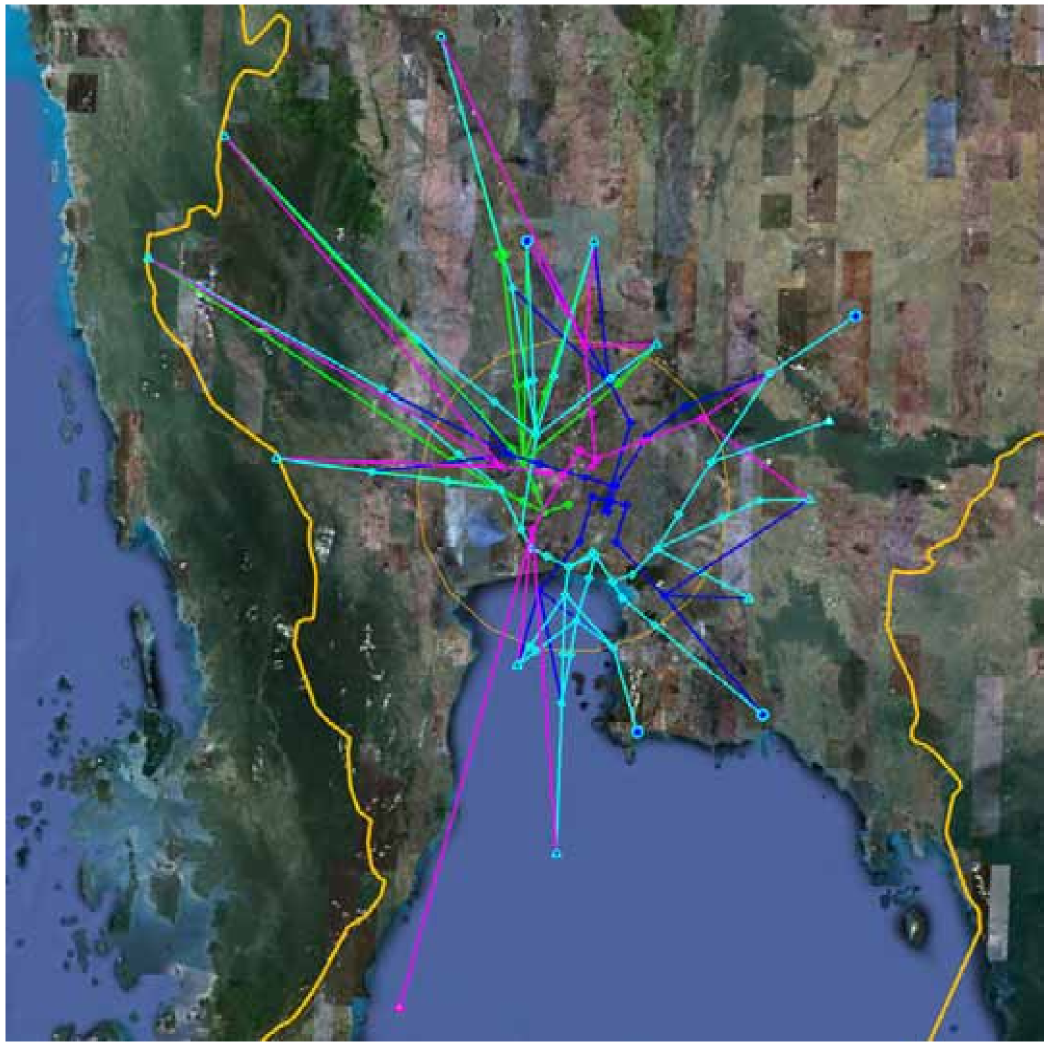
- Prominent South→ North wind from the Sea (9 months/year)
- North→ South Wind in “Winter”
- Every now and then, strange wind contradicting wind pattern at VTBS and VTBD

Baseline Scenario: Current TMA and Route Structure

Airports

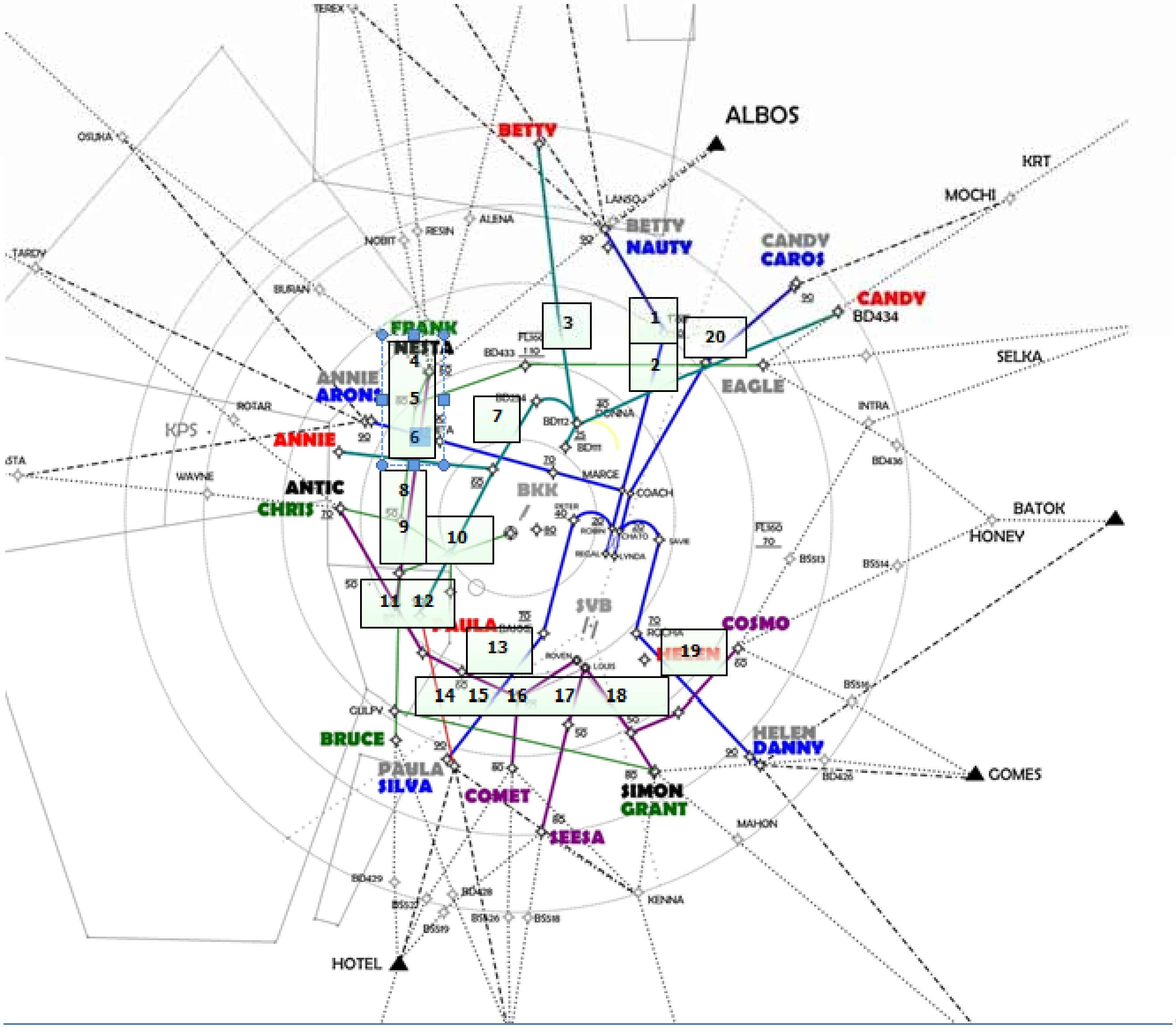
- 2 airports within close vicinity
  - VTBS – Suvarnabhumi – 2 runways (01/19)
  - VTBD – Don Mueang – 2 runways (03/21)
- Mostly flat terrain

Current SID/STAR VTBS19 and VTBD21



Baseline Scenario:

Current SIDs/STARs and their Limitations

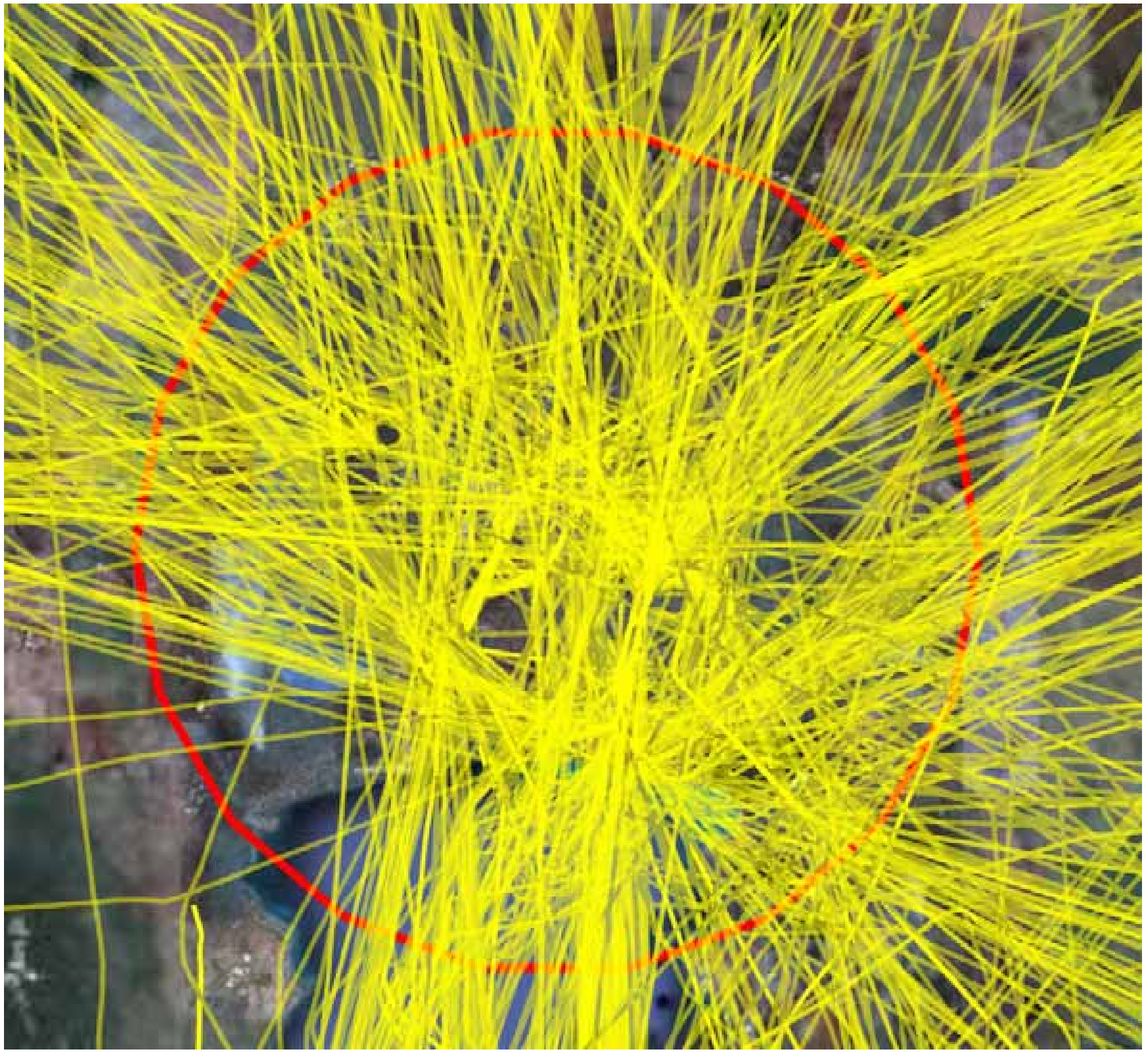


Baseline Scenario:

Current SIDs/STARs and their Limitations

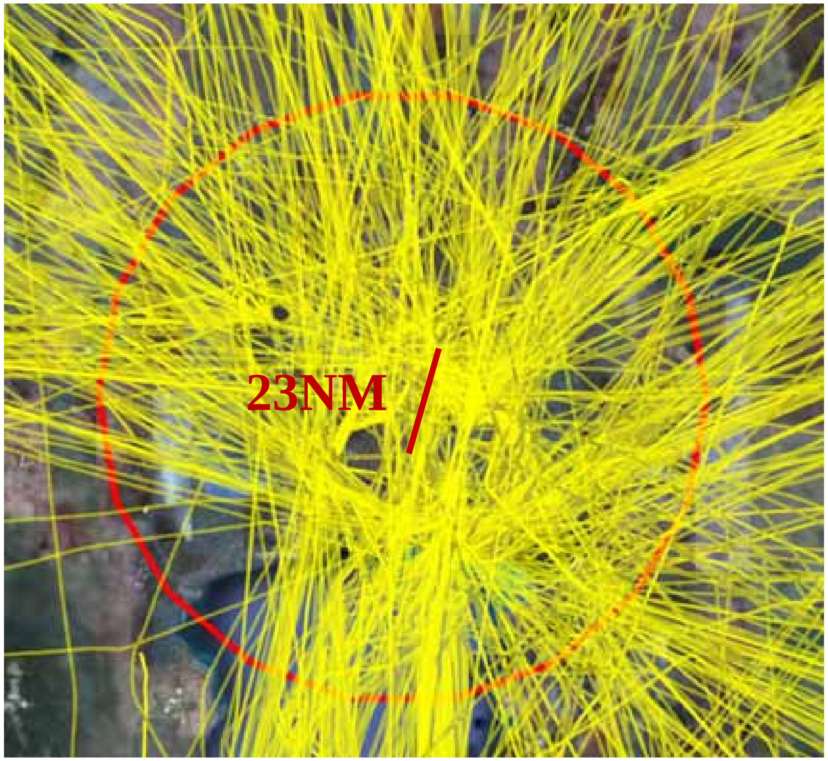
- 20 Crossing Points – potential conflicts
- Requires a lot of radar vectoring and levelling off
  - both during departure and arrival
  - increase workload for both ATCs and pilots
  - High fuel consumption and CO_2 emission due to low-altitude radar vectoring and restricted climb during departures
- Prone to TCAS alerts and aircraft incidents

One day of actual RADAR track



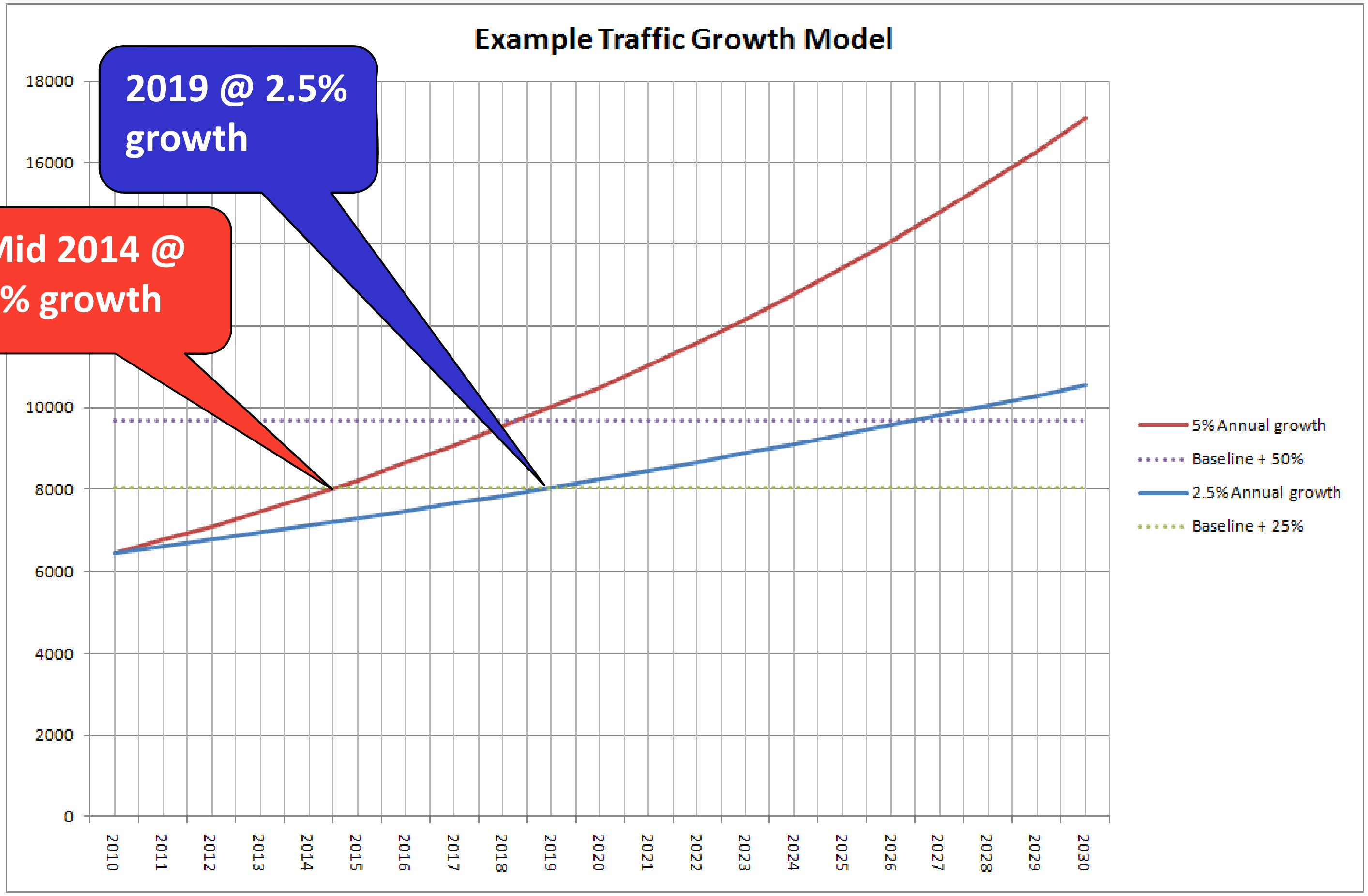
Baseline Scenario:

Current SIDs/STARs and their Limitations



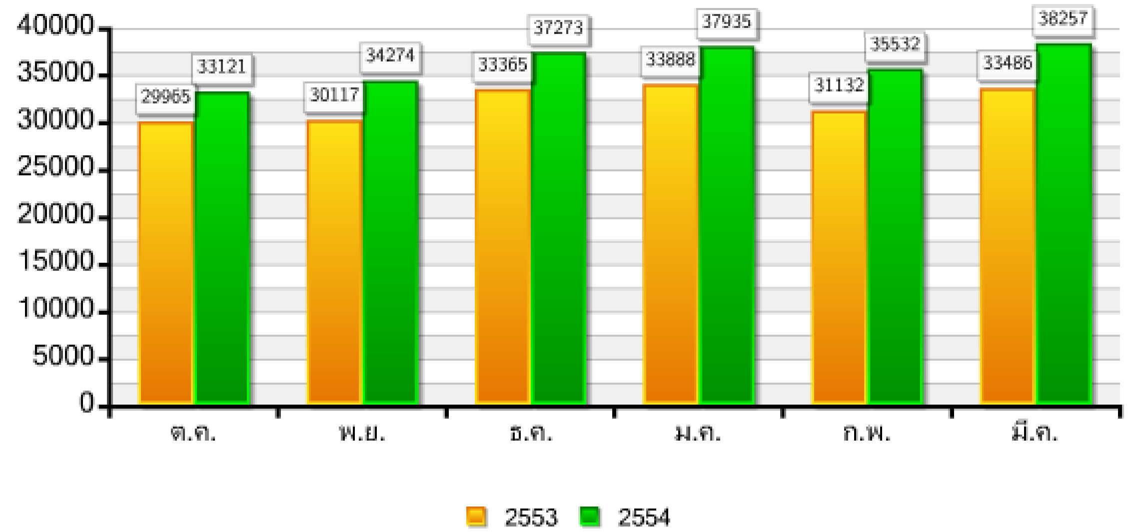
- RADAR vectoring for extended downwind now extended beyond 20 NM
  - Beyond the service area of ILS as depicted in ICAO Annex 10
  - Some false-ILS captures have been reported
  - Safety hazards, especially for future parallel approach operations

Expected Growth and Limitations: Why 125% and When?



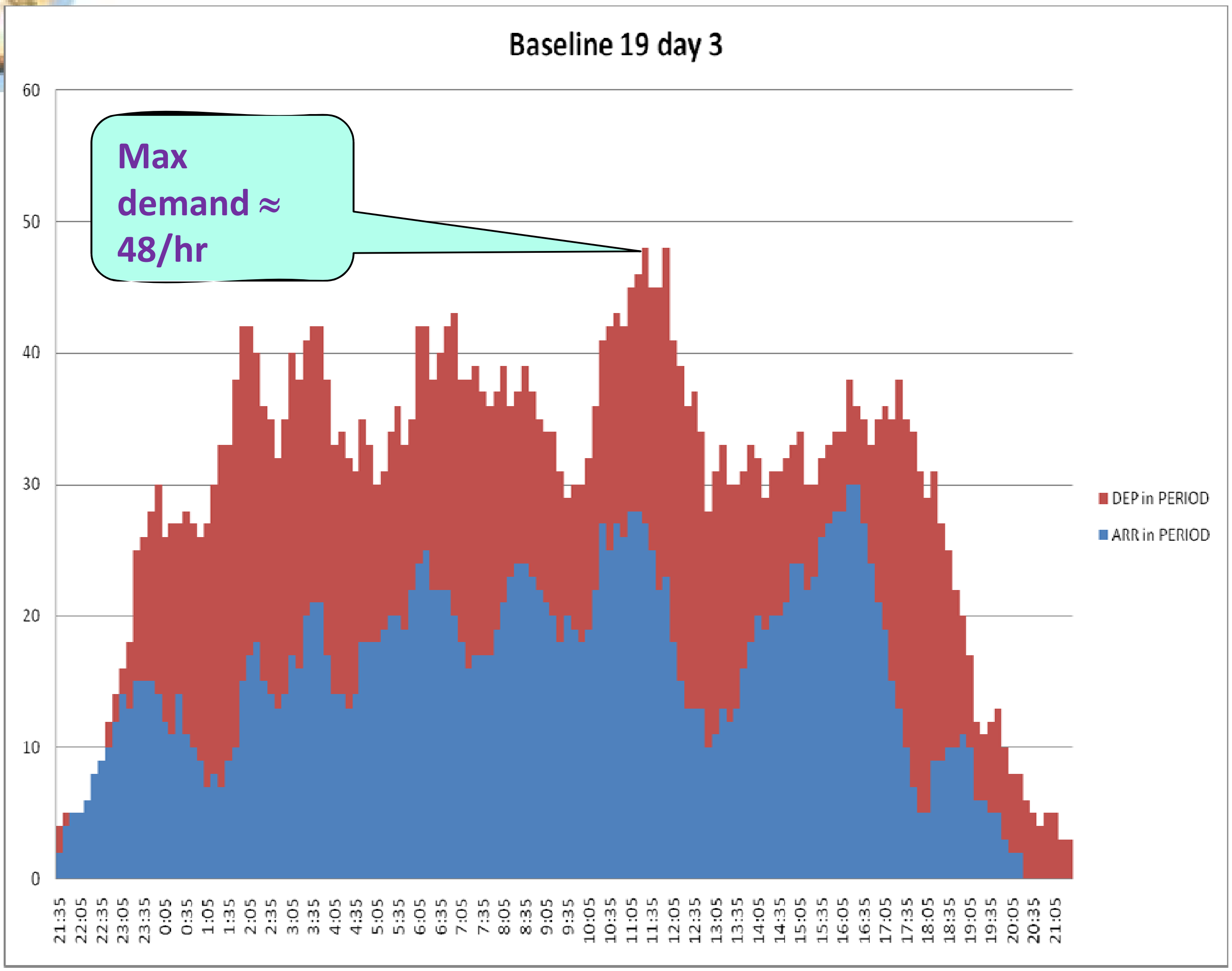
Actual Growth: 10% ++

ปริมาณเที่ยวบินพาณิชย์ประจำปีงบประมาณ 2554

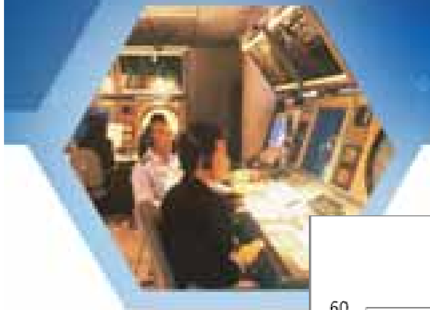


เดือน	2553	2554	ผลการเปลี่ยนแปลง	% เปลี่ยนแปลง
ต.ค.	29,965	33,121	3,156	10.53 %
พ.ย.	30,117	34,274	4,157	13.80 %
ธ.ค.	33,365	37,273	3,908	11.71 %
ม.ค.	33,888	37,935	4,047	11.94 %
ก.พ.	31,132	35,532	4,400	14.13 %
มี.ค.	33,486	38,257	4,771	14.25 %
รวม	191,953	216,392		

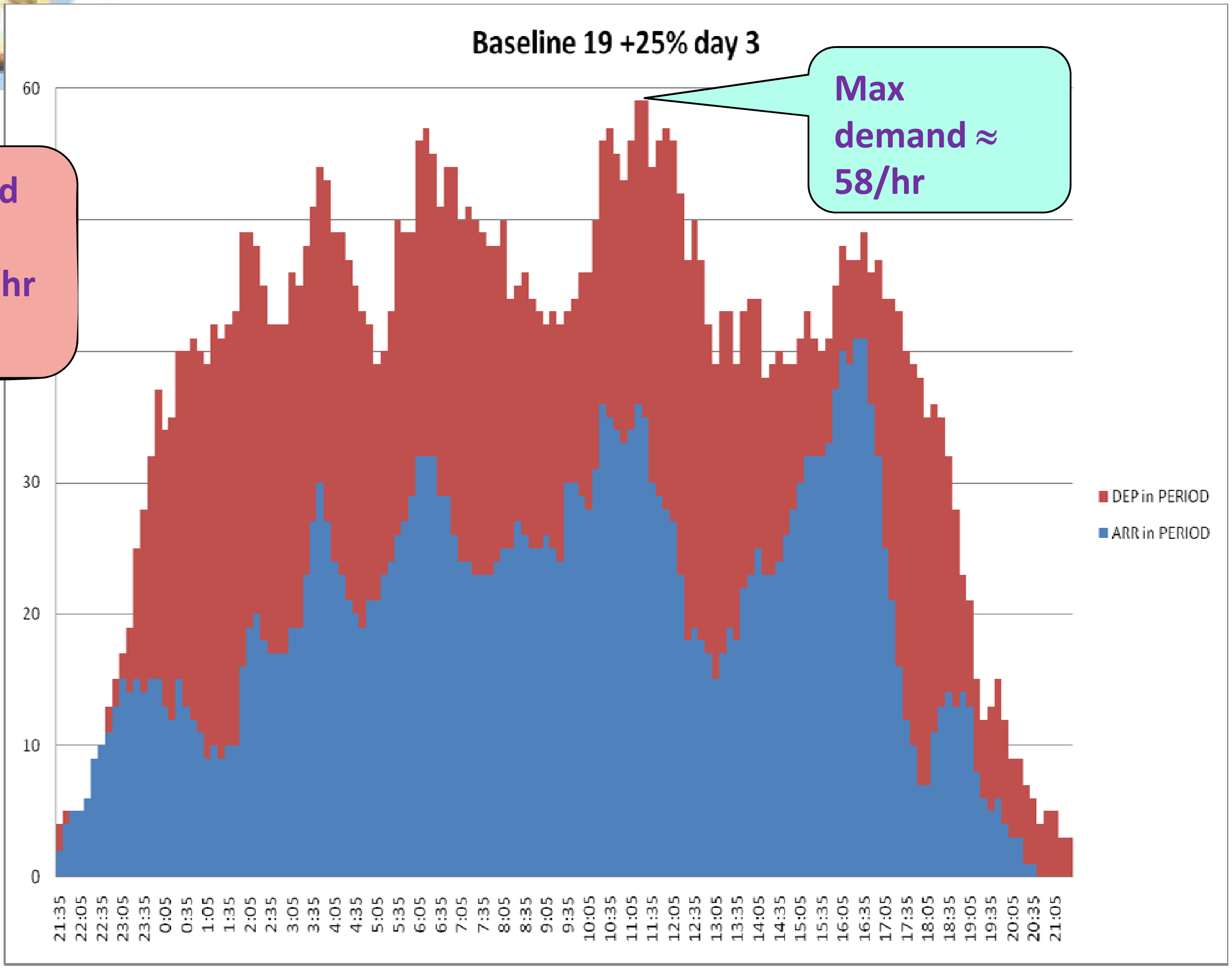
Throughput – Baseline 19 ops



Throughput –Baseline 19 ops +25%



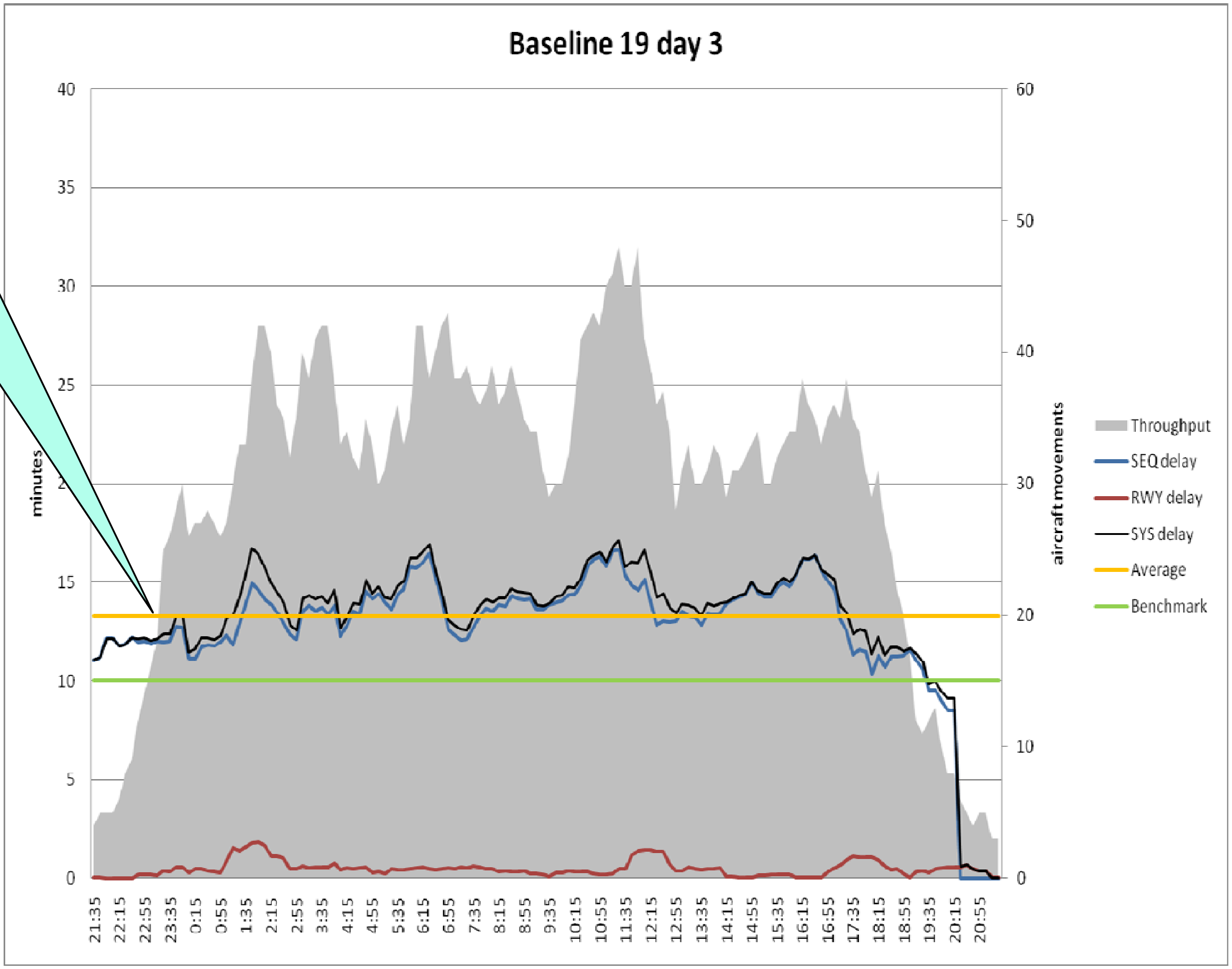
AOT declared runway capacity 76/hr



Delay – Baseline 19 ops (TMA inner)

Ave delay ≈ 13.5 mins per flight -

total ≈ 340 mins delay per operating hour

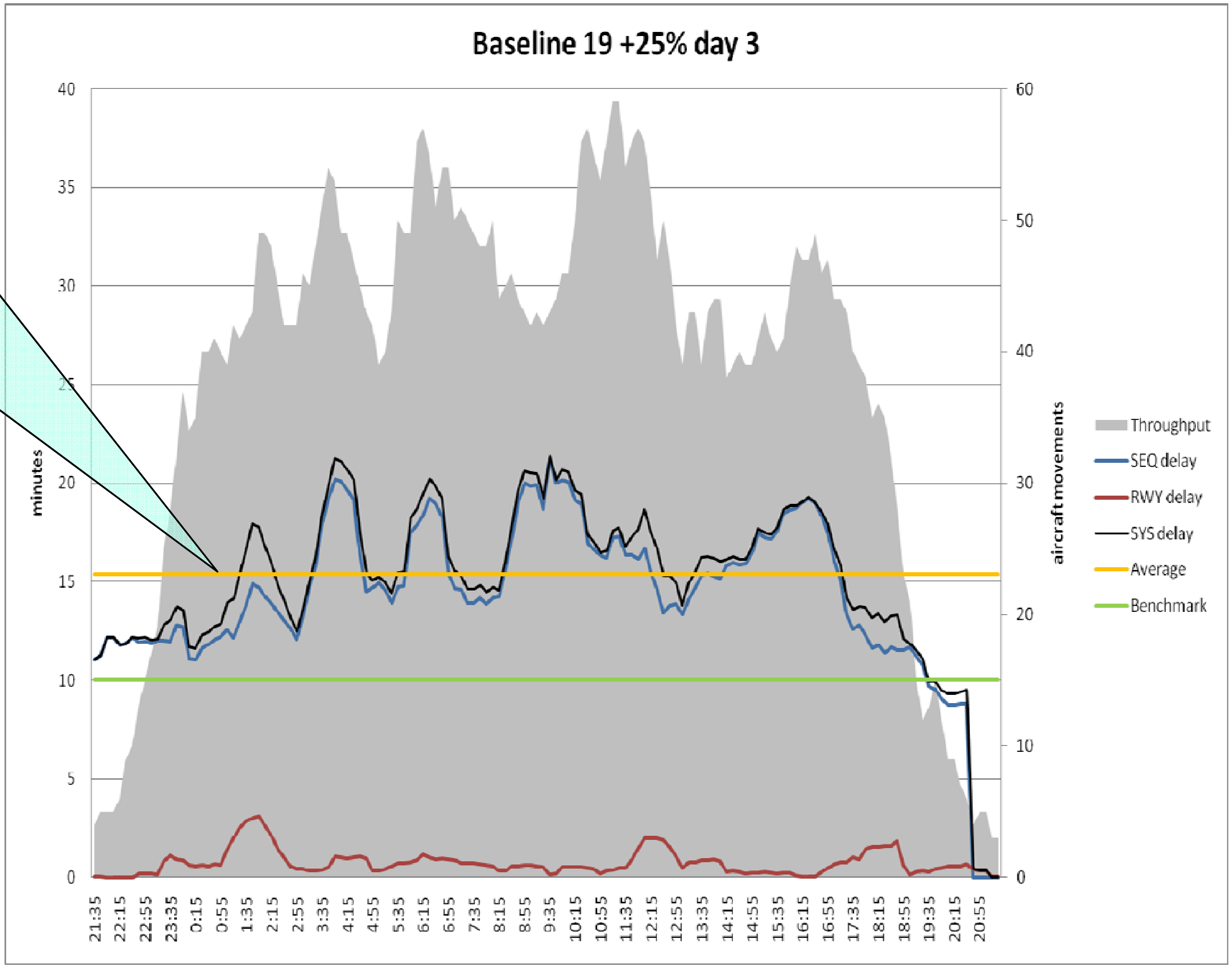


Delay – Baseline 19 ops + 25% (TMA inner)

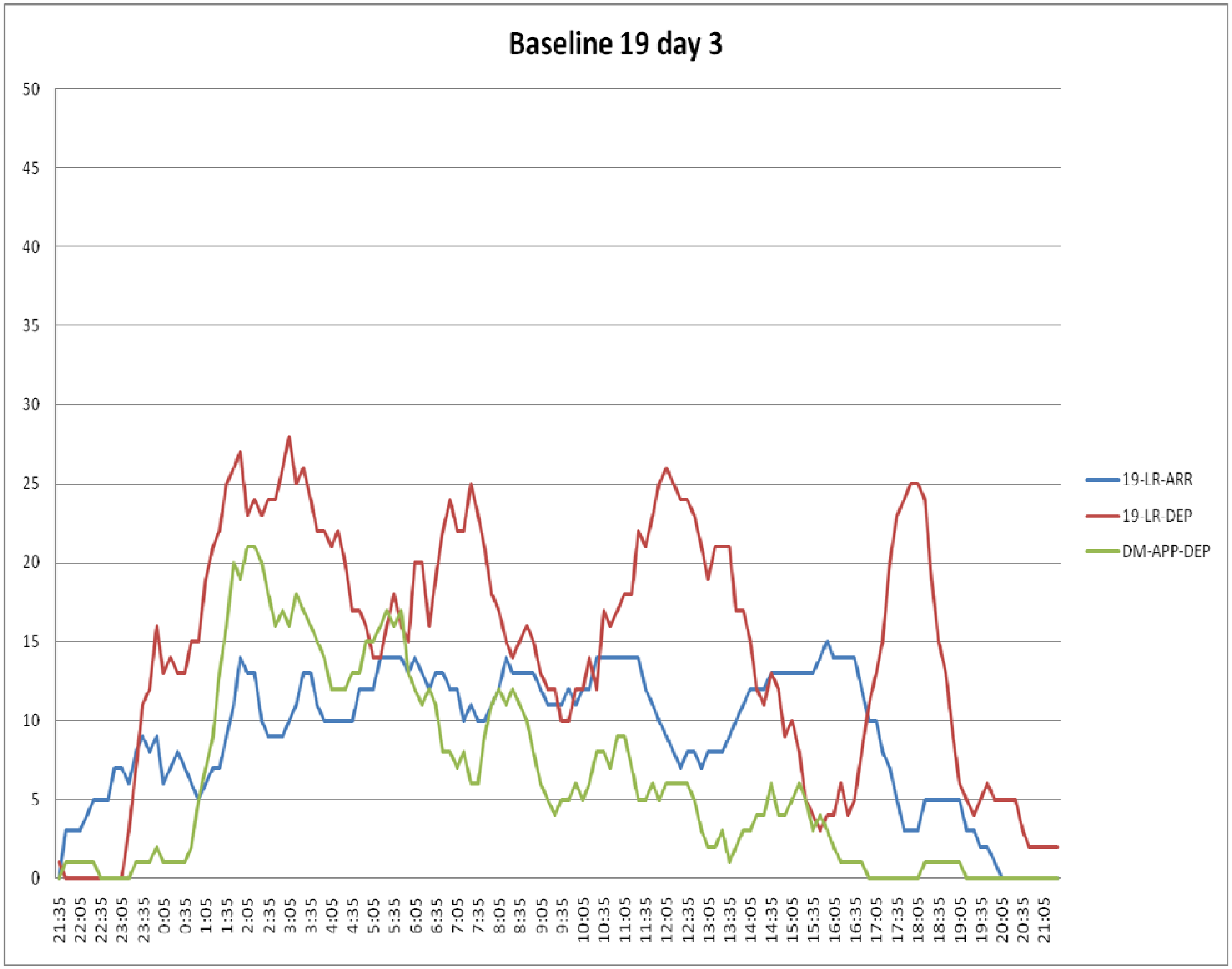
Ave delay ≈ 15.5 mins per flight -

total ≈ 550 mins delay per operating hour

(+ 62% over baseline)

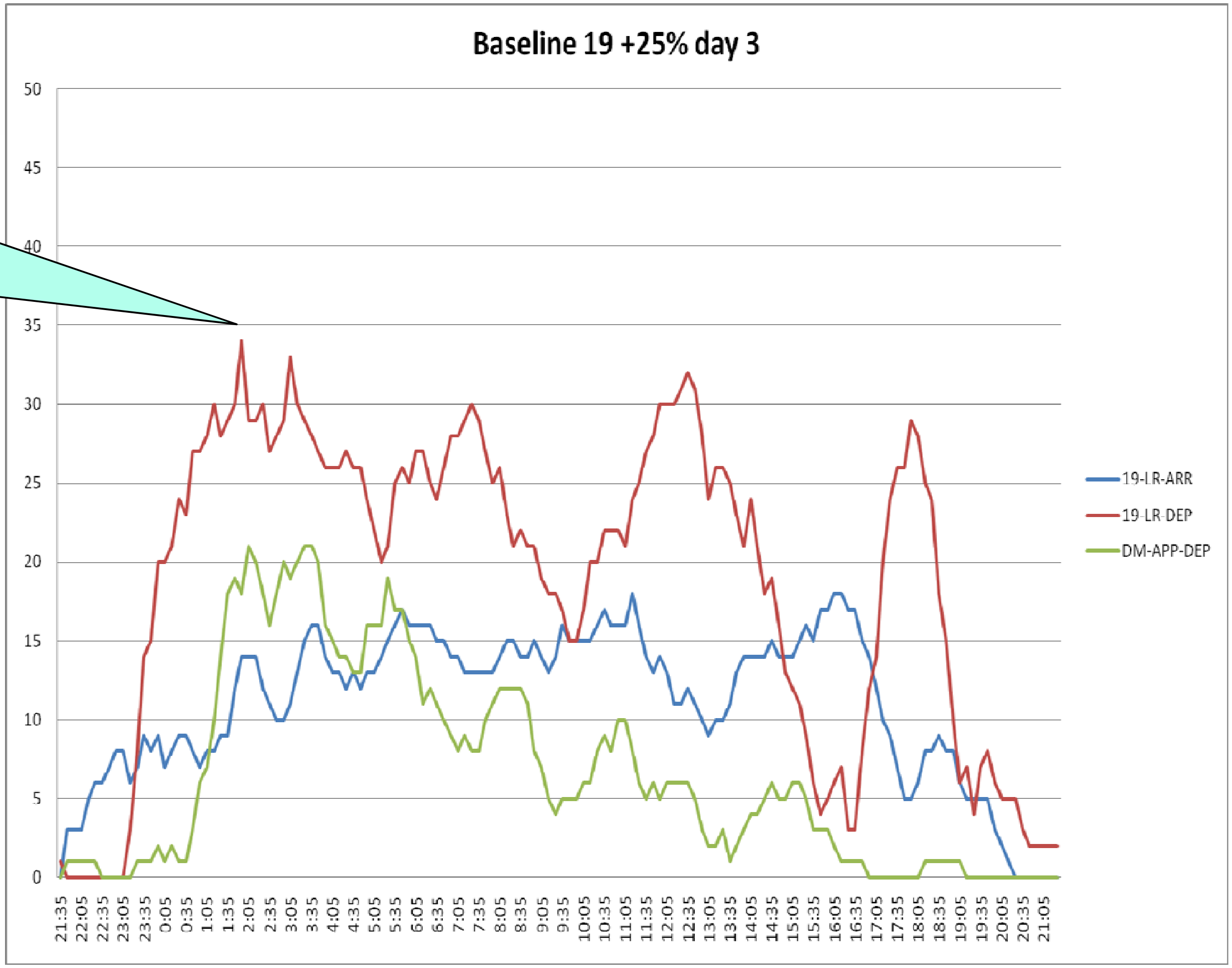


Workload - Baseline 19 ops (TMA inner)



Workload - Baseline 19 ops + 25% (TMA inner)

≈ 18% increase in workload in inner TMA sectors



Agreements on Project Objectives, Scope and Performance Matrix

Agreement on Project Objectives

The National Working Group at its 21st Meeting endorsed the following objective statement.

"Enable the maximum use of potential runway capacity

Subject to

- **Maintain system safety**
- **Minimise system delays**
- **Optimise controller workload**
- **Minimise environmental impact"**

Agreement on Project Scope

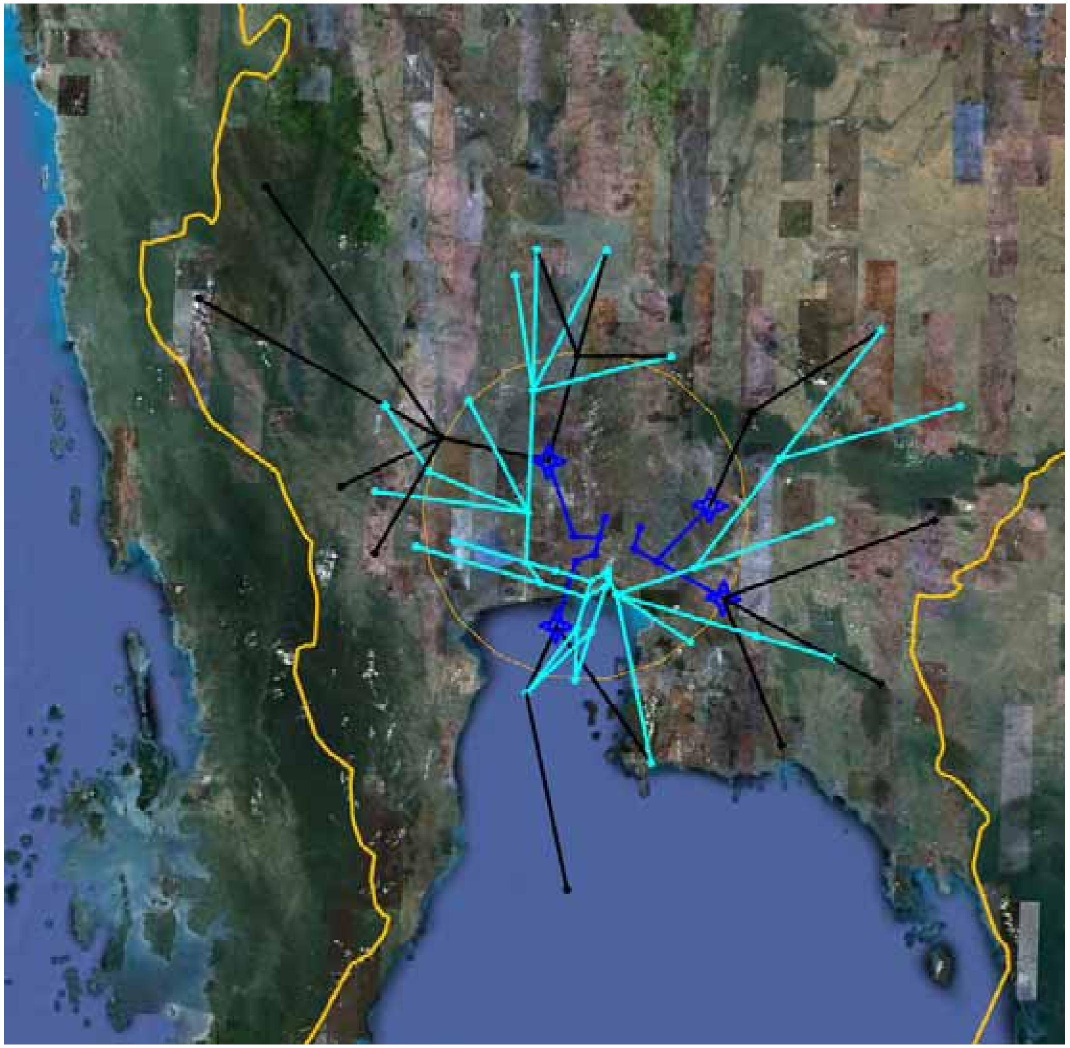
- Revision of SID and STAR for Suvarnabhumi and Don Mueang
- Introduction of RNP APCH with Baro-VNAV
- Revise Airspace Structure and Existing Conventional IFPs as Necessary

On-going Works on Revising SID and STAR

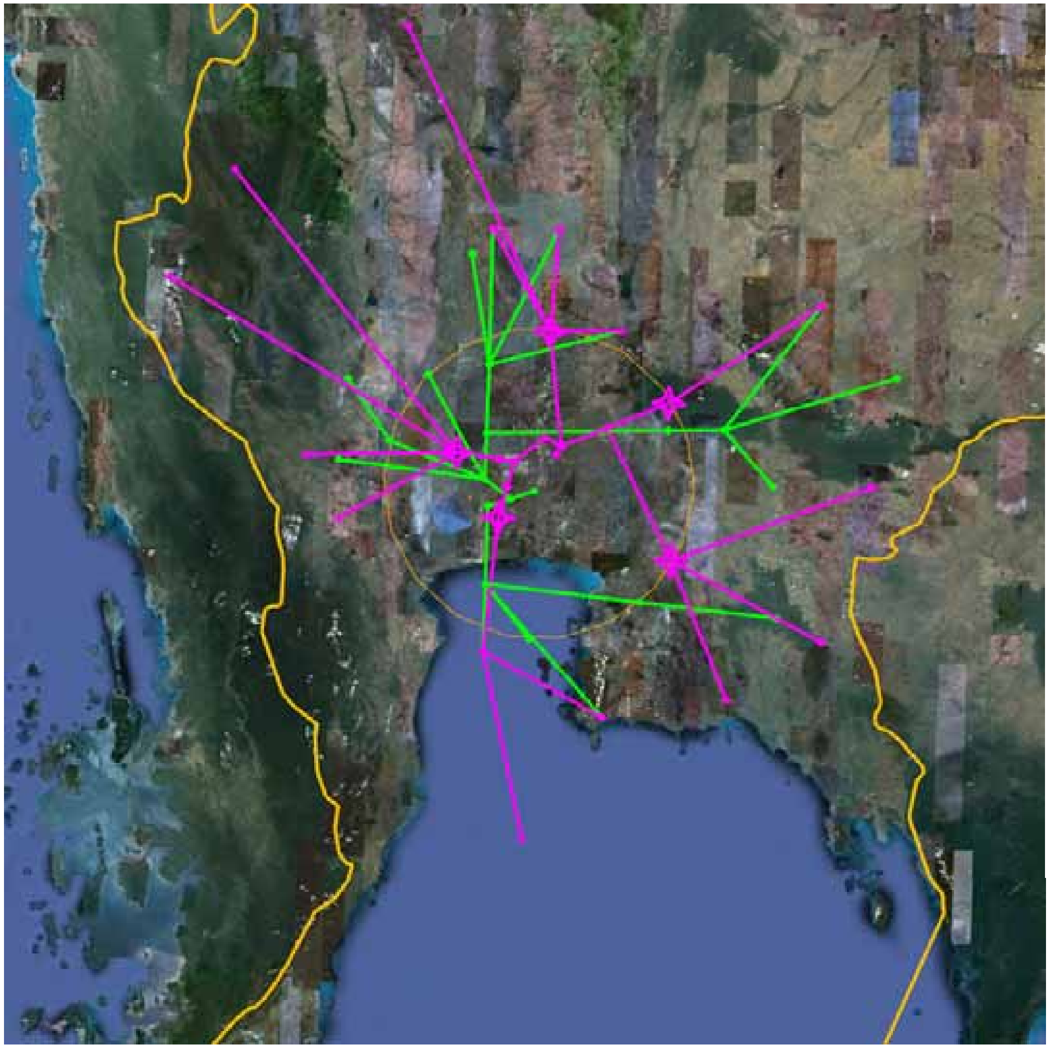
- Two alternative options are being evaluated
  - Option 1: Open STAR to downwind
  - Option 2: Point Merge

Option 1: Open-STAR

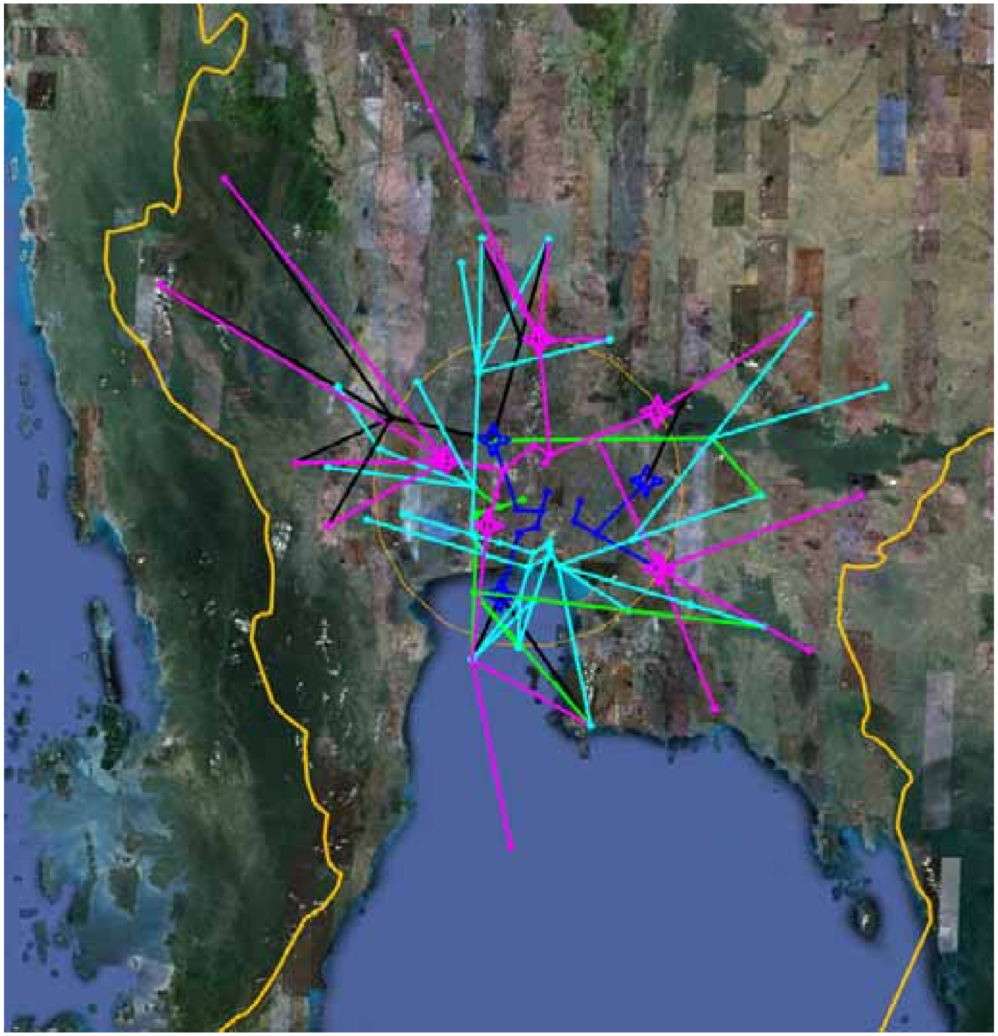
Proposed Open-STAR with SID VTBS RWY 19

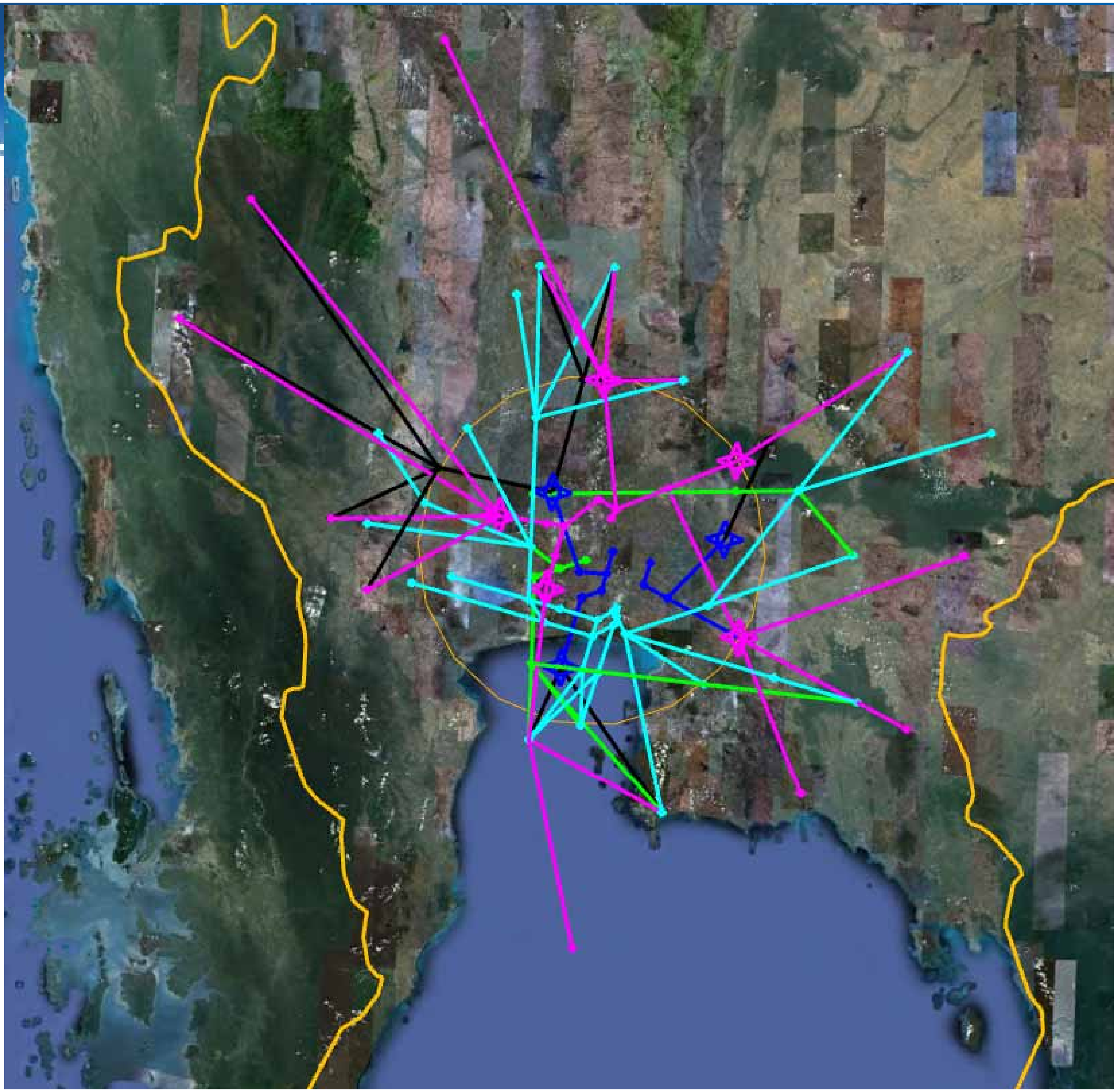


Proposed SID/STAR VTBD RWY 21



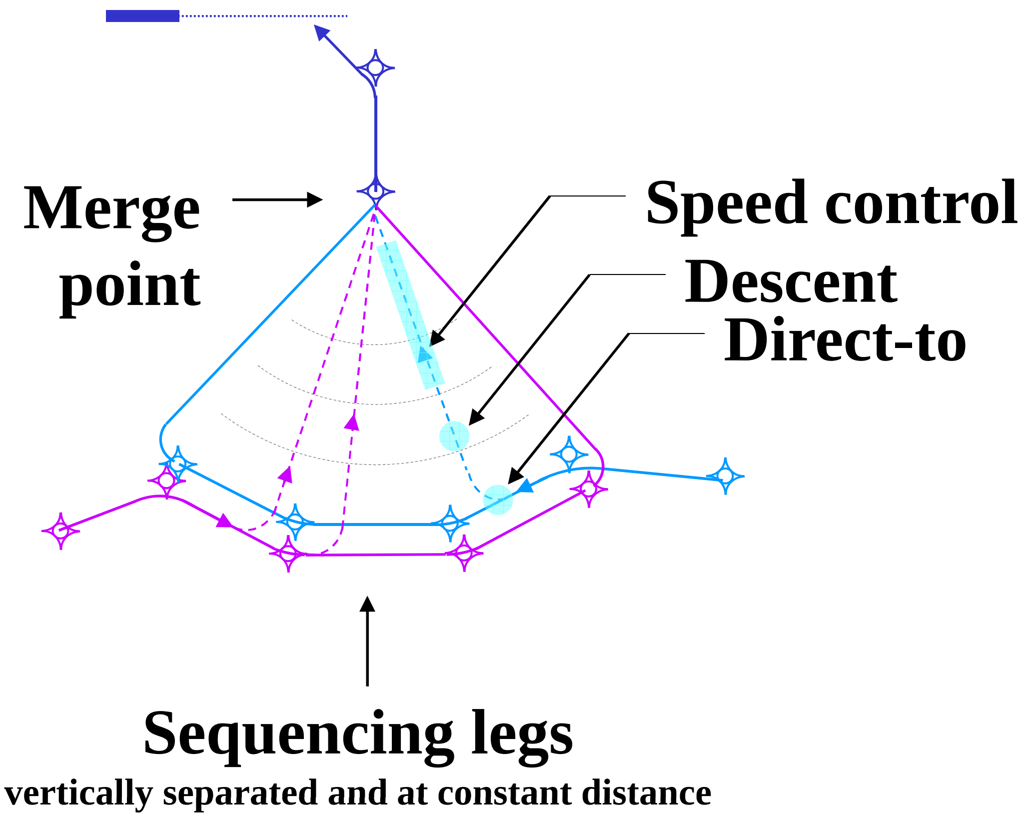
Overall Open-STAR Proposal





Option 2: Point-Merge

Eurocontrol Point Merge Concept



Point-Merge Concept

- Developed by Eurocontrol
- Endorsed by ICAO and documented in ICAO Doc. 9931: Continuous Descent Operations (CDO) Manual

Doc 9931
AN/476

Continuous Descent Operations (CDO) Manual

Notice to Users

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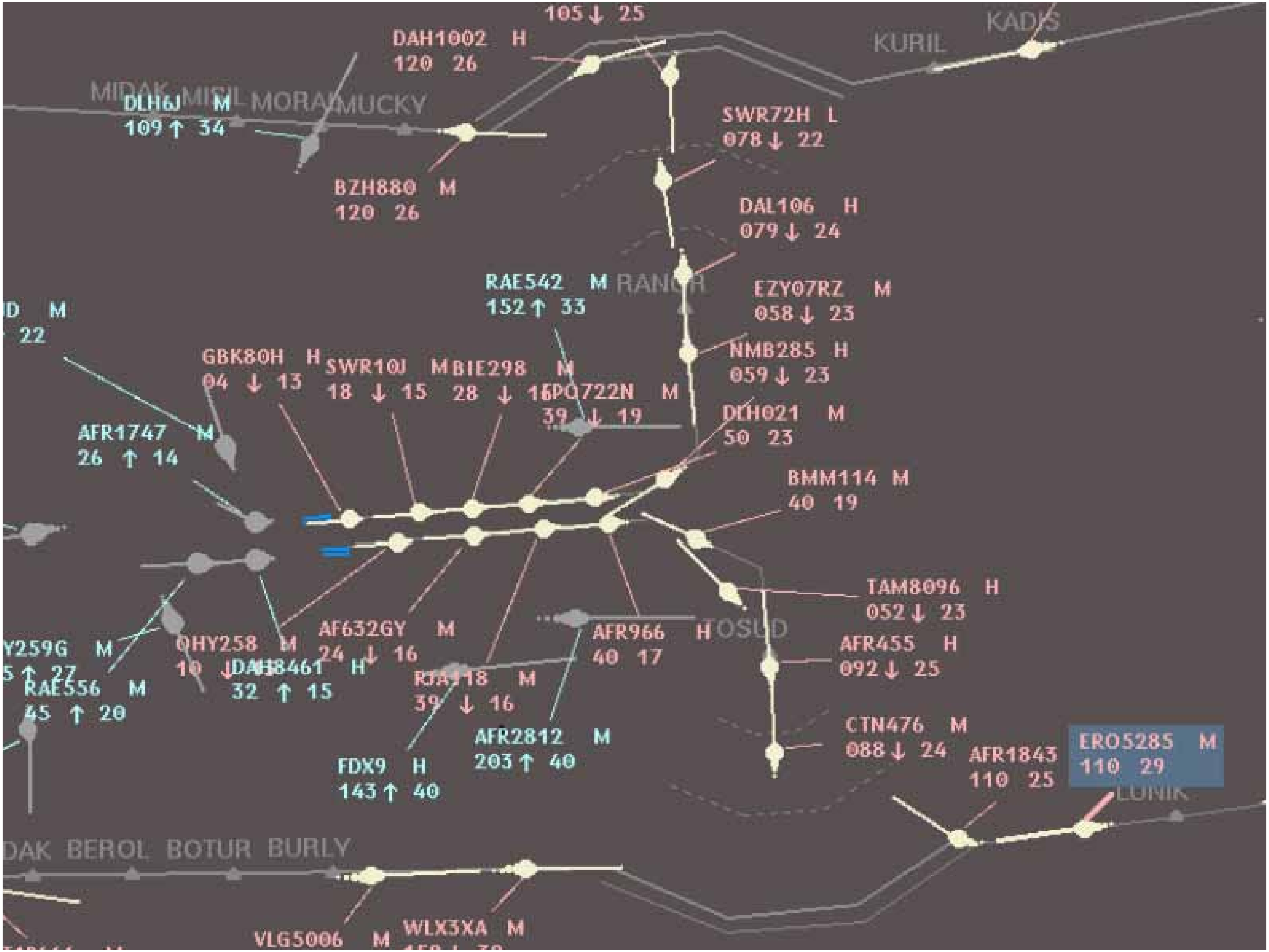
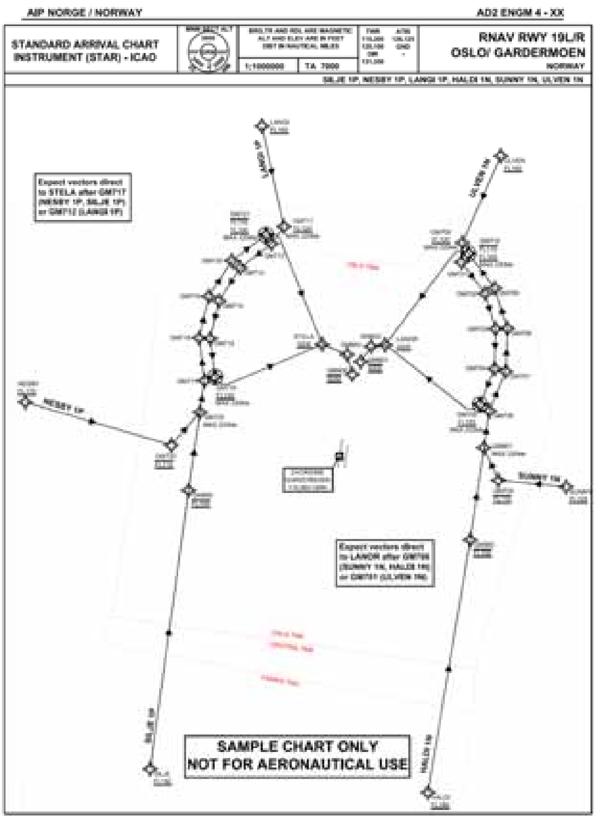
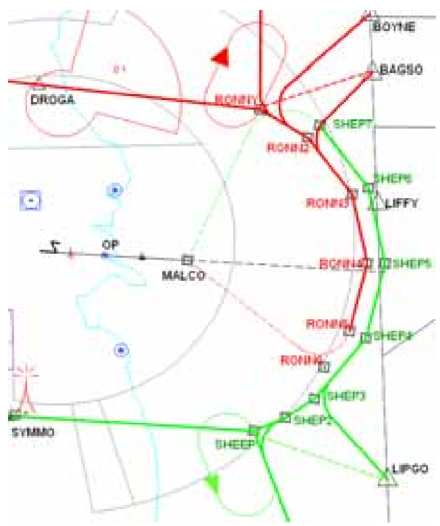
Advance edition (unedited)

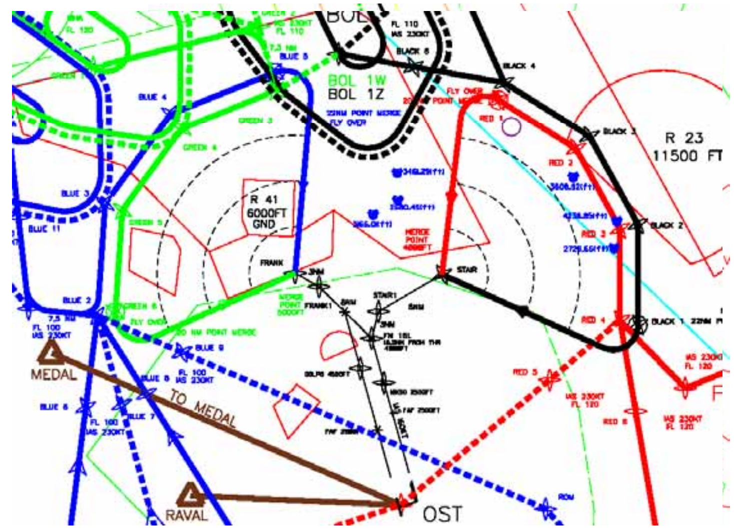

105 ↓ 25
DAH1002 H
120 26
KADIS
KURIL
MIDAK MISIL MORAL MUCKY
DLH6J M
109 ↑ 34
SWR72H L
078 ↓ 22
BZH880 M
120 26
DAL106 H
079 ↓ 24
RAE542 M
152 ↑ 33
RANOR
EZY07RZ M
058 ↓ 23
D M
22
GBK80H H
04 ↓ 13
SWR10J M
18 ↓ 15
BIE298 M
28 ↓ 16
EPO722N M
39 ↓ 19
NMB285 H
059 ↓ 23
DLH021 M
50 23
AFR1747 M
26 ↑ 14
BMM114 M
40 19
TAM8096 H
052 ↓ 23
AF632GY M
24 ↓ 16
AFR966 H
40 17
TOSUD
AFR455 H
092 ↓ 25
Y259G M
5 ↑ 27
QHY258 M
10 ↓
DAH8461 H
32 ↑ 15
RJA118 M
39 ↓ 16
RAE556 M
45 ↑ 20
AFR2812 M
203 ↑ 40
CTN476 M
088 ↓ 24
AFR1843
110 25
ERO5285 M
110 29
LUNIK
FDX9 H
143 ↑ 40
DAK BEROL BOTUR BURLY
VLG5006 M
WLX3XA M

On-going Works on Revising SID and STAR: Option 2 – Point Merge

- Oslo, Dublin, Rome
- Others interested (Geneva, Brussels, Munich, …)





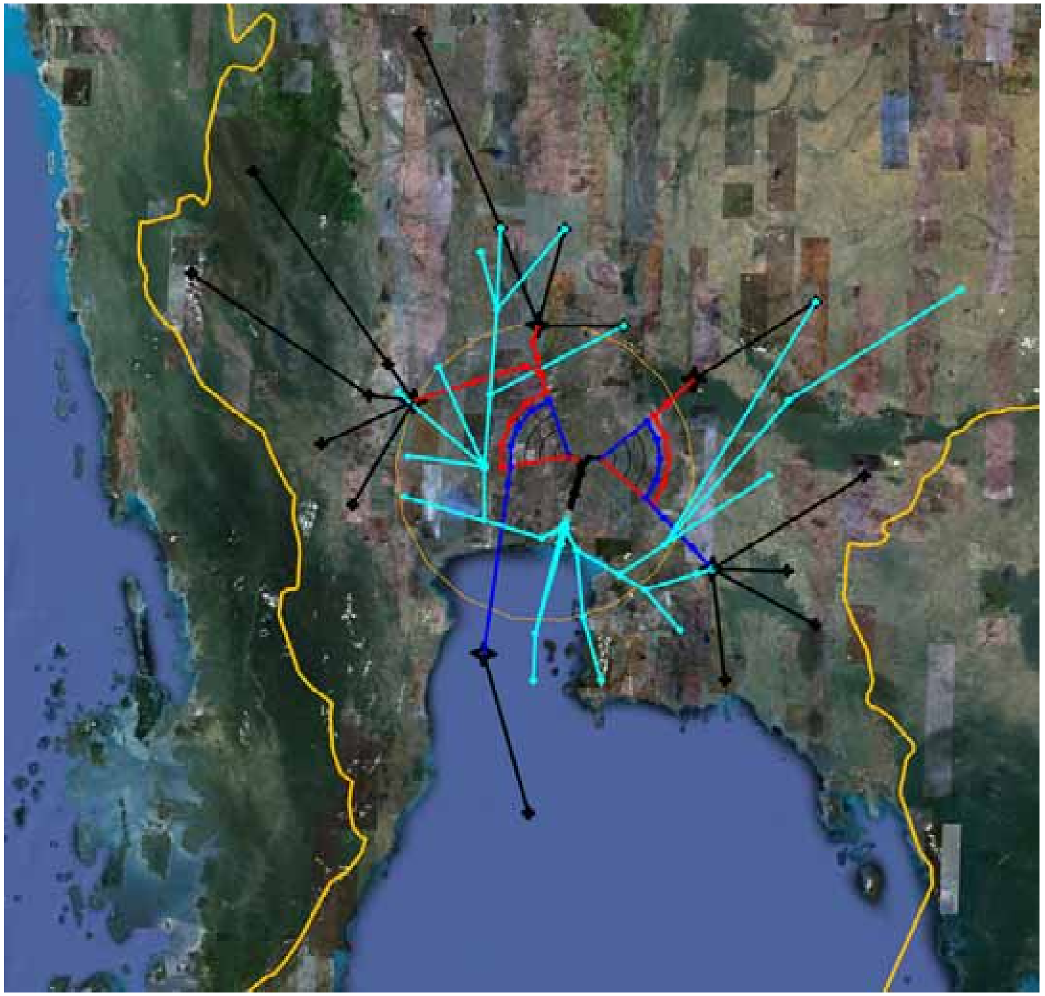


AVINOR

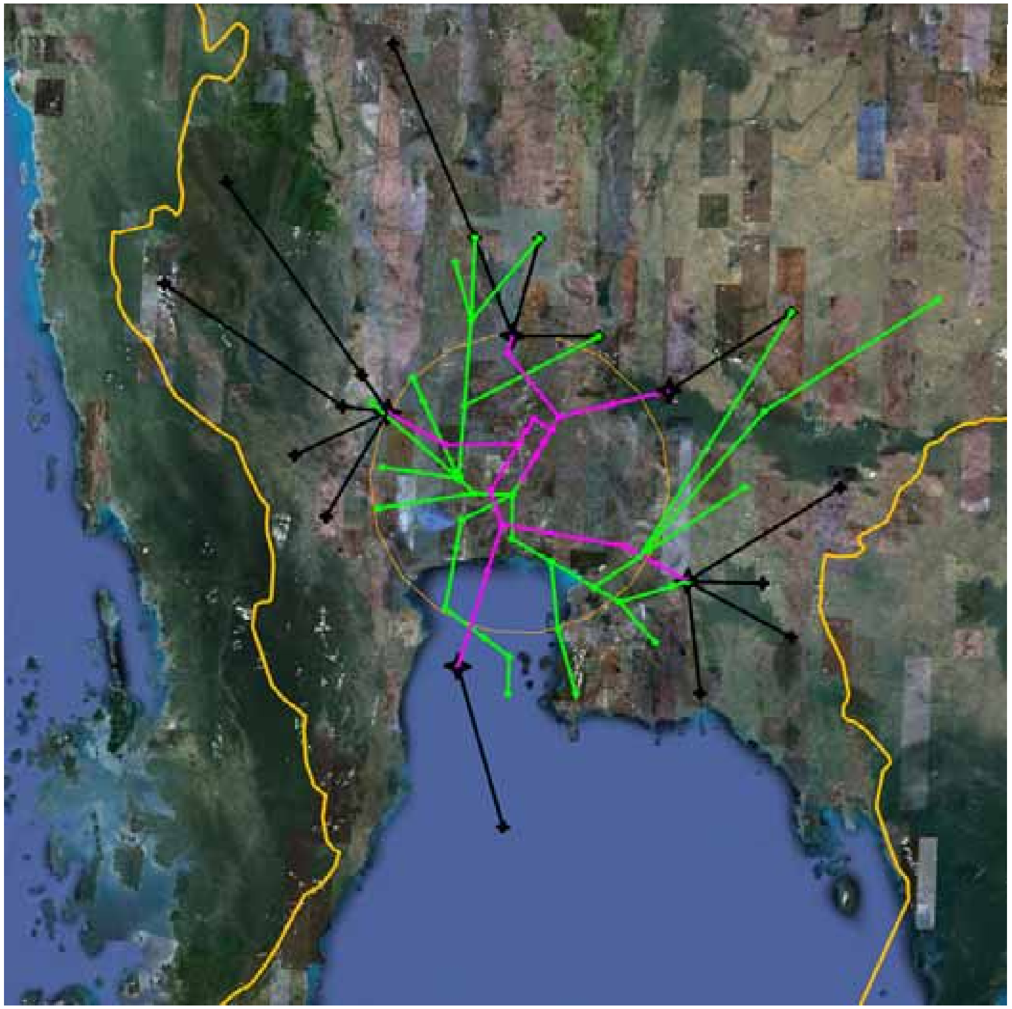
IRISH AVIATION AUTHORITY
ÚDARÁS EITLÍOCHTA NA hÉIREANN

ENAV S.p.A.

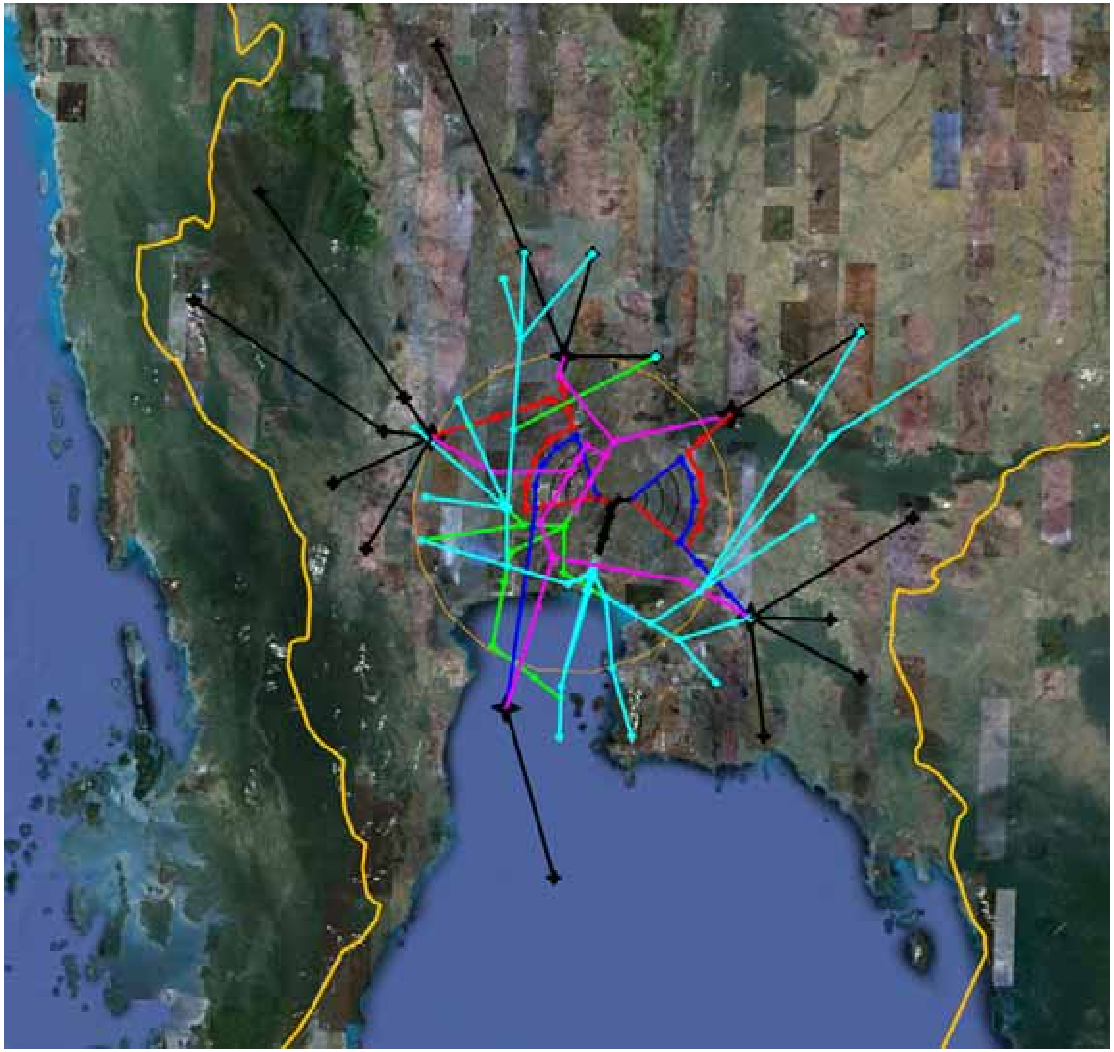
Proposed Point Merge-STAR with SID VTBS RWY 19

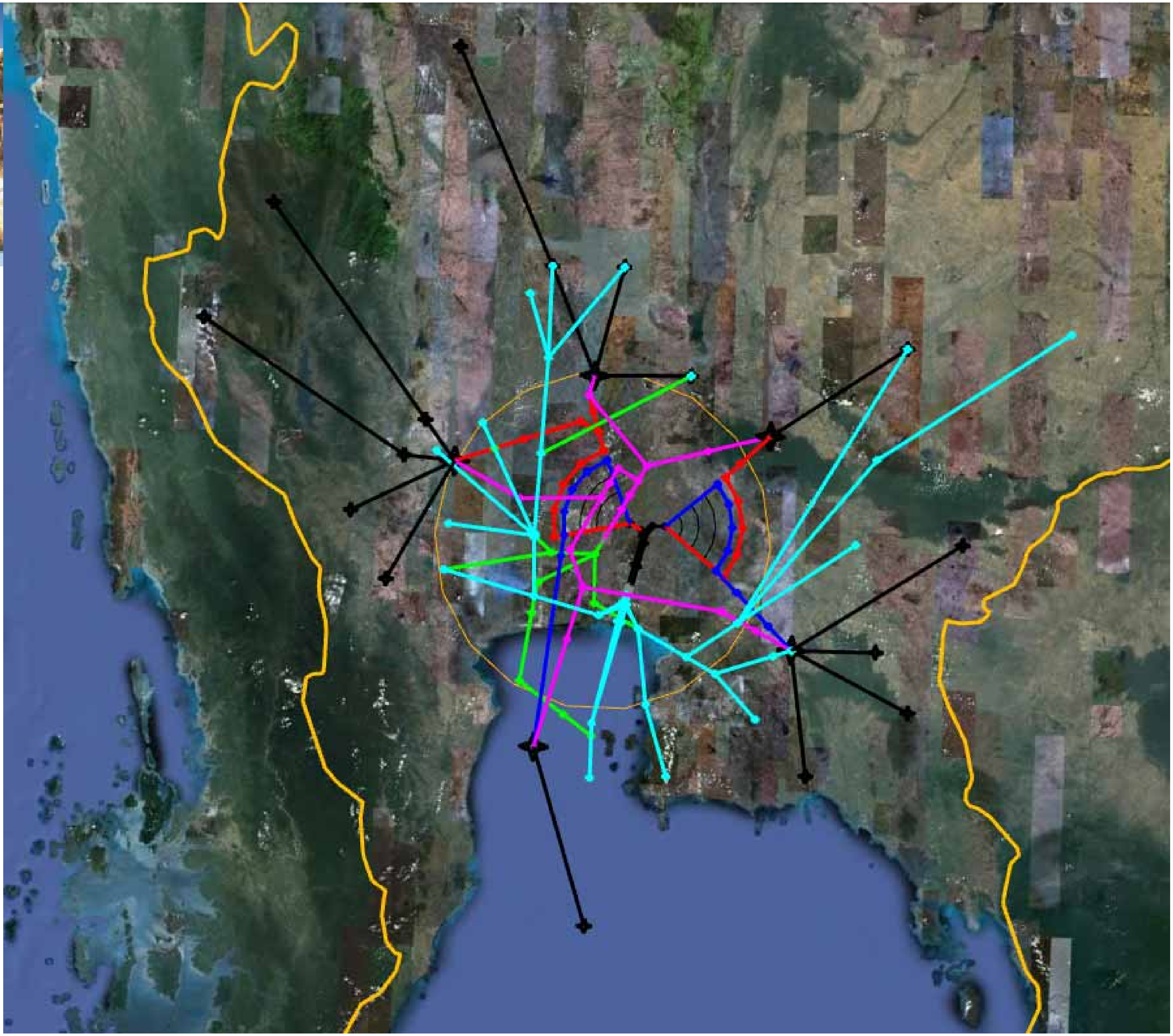


Proposed SID/STAR VTBD RWY 21



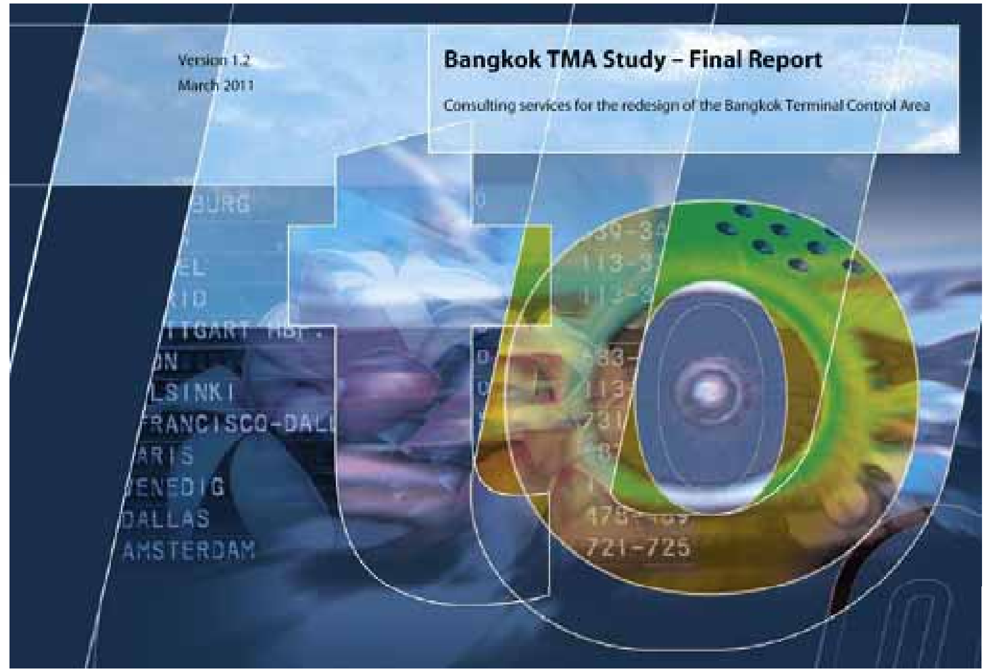
Overall Point Merge-STAR Proposal





Performance Evaluation

Evaluation Methodology



Performance Comparison:

Open-STAR vs. Point Merge

- Use fast-time simulation tool as utilized by Eurocontrol
- Conducted by independent experts (To70).
  - Acceptance Committee from ATC Suvarnabhumi, ATC Don Mueang and Procedure Design
- Expert recommendations received by ICAO/IATA PBN Go-Team.

Agreement on Project Objectives

The National Working Group at its 21st Meeting endorsed the following objective statement.

“Enable the maximum use of potential runway capacity

Subject to

- **Maintain system safety**
- **Minimise system delays**
- **Optimise controller workload**
- **Minimise environmental impact”**

Traffic Demand Schedule

Traffic demand levels based on percentage over current traffic

Level	Max Arrival Demand	Max Departure Demand	Max Combined Demand
125%	40	40	62
150%	47	46	75
175%	54	52	84
200%	63	66	105

Delay Performance

Open-STAR

	VTBS Enhanced (Mixed)			
	125%	150%	175%	200%
Average Arrivals (mins)	3.64	11.62	50.78	63.08
Average Departure (mins)	0.75	2.37	3.50	14.13
Average Combined (mins)	4.39	13.98	54.28	77.21
Max Arrival (mins)	11.10	40.60	128.09	150.13
Max Departure (mins)	7.66	13.14	152.84	172.79
Max Combined (mins)	12.82	42.36	152.84	172.79

Table 23 - Summary of Delays for VTBS Capacity Analysis

Point-merge

	Point Merge Enhanced (Mixed)				Point Merge Enhanced (IND)			
	125%	150%	175%	200%	125%	150%	175%	200%
Average Arrivals (mins)	1.64	3.89	11.66	35.32	1.09	2.27	3.85	11.58
Average Departure (mins)	0.88	1.50	3.81	18.50	0.64	1.44	2.34	5.77
Average Combined (mins)	2.52	5.39	15.47	53.83	1.73	3.72	6.20	17.35
Max Arrival (mins)	4.87	12.75	43.72	80.07	3.38	8.01	13.69	39.67
Max Departure (mins)	7.65	10.89	20.26	36.09	2.05	5.47	7.48	18.99
Max Combined (mins)	7.69	13.93	48.73	111.45	4.46	10.12	15.89	50.14

Table 26 - Summary of Delays for Point Merge Capacity Analysis

Capacity & Workload Performance

Scenario	Estimated Capacity as % of Current Busiest Day Demand	Max Runway Movement Rate/hr	Average Delay Range Per Flight (mins)	Max Average TMA Sector Workload
Point Merge Independent Mode	175% - 200%	78 - 90	6.20 – 17.35	20% – 25%
Point Merge Mixed Mode	150% - 175%	67 - 76	5.39 – 15.47	20% - 25%
VTBS Mixed Mode	150%	68	13.98	20% - 22%

Environment Performance: Track Miles

Average Distances from 100nm to Threshold (19L/R) from:	Enhanced Baseline	VTBS Enh Design	Point Merge/Point Merge Enh Design
NW	106.6nm	133.0nm (+26.4nm)	125.9nm (+19.3nm)
South	127.9nm	136.0nm (+8.1nm)	157.8nm (+29.9nm)
NE	104.2nm	121.5nm (+17.3nm)	103.3nm (-0.9nm)
SE	125.2nm	123.7nm (-1.5nm)	135.4nm (+10.2nm)
Average	**116.0nm**	**128.55nm (+12.6nm)**	**130.6nm (+14.6nm)**

Table 10 - STAR Path Length Comparison

Environment Performance: Track Miles

Average Distances from VTBS (19L/R) to 100nm	Enhanced Baseline	VTBS/VTBS Enh Design	Point Merge/Point Merge Enh Design
NW	120.2nm	118.5nm (-1.7nm)	122.6nm (+2.4nm)
South	101.8nm	105.4nm (+3.6nm)	100.3nm (-1.5nm)
NE	124.1nm	117.5nm (-6.6nm)	128.8nm (+4.7nm)
SE	108.0nm	104.3nm (-3.7nm)	106.8nm (-1.2nm)
Average	**113.5nm**	**111.4nm (-2.1nm)**	**114.6nm (+1.1nm)**

Table 11 - SID Path Length Comparison

Environment Performance: Track Miles

Average Track Mile Delta

= (Design Track Miles – Baseline Track Miles) x Actual # of Flights

	VTBS Enh Design	Point Merge Enh Design
Arrivals	18.4nm	8.2nm
Departures	-1.8nm	1.7nm

Table 13 - Average Track Mile Delta per Flight for Capacity Analysis

Environment Performance: Emission

	Open-STAR Design	Point Merge Design
Sequencing Method	Low altitude radar vectoring at 3000-7000 ft	High altitude planned sequencing leg at about 10000 ft
Design Overhead over Enhanced Baseline	Arrival +14.1 NM Departure -1.8 NM	Arrival +8.2 NM Departure +1.7 NM
Trajectory Predictability	Low – Aircraft is required to fly heading mode due to radar vectoring.	High – Pilot can utilize FMS capability, more suitable for CDO operation
Emission Level due to Sequencing	Higher	Lower

Environment Performance: Noise

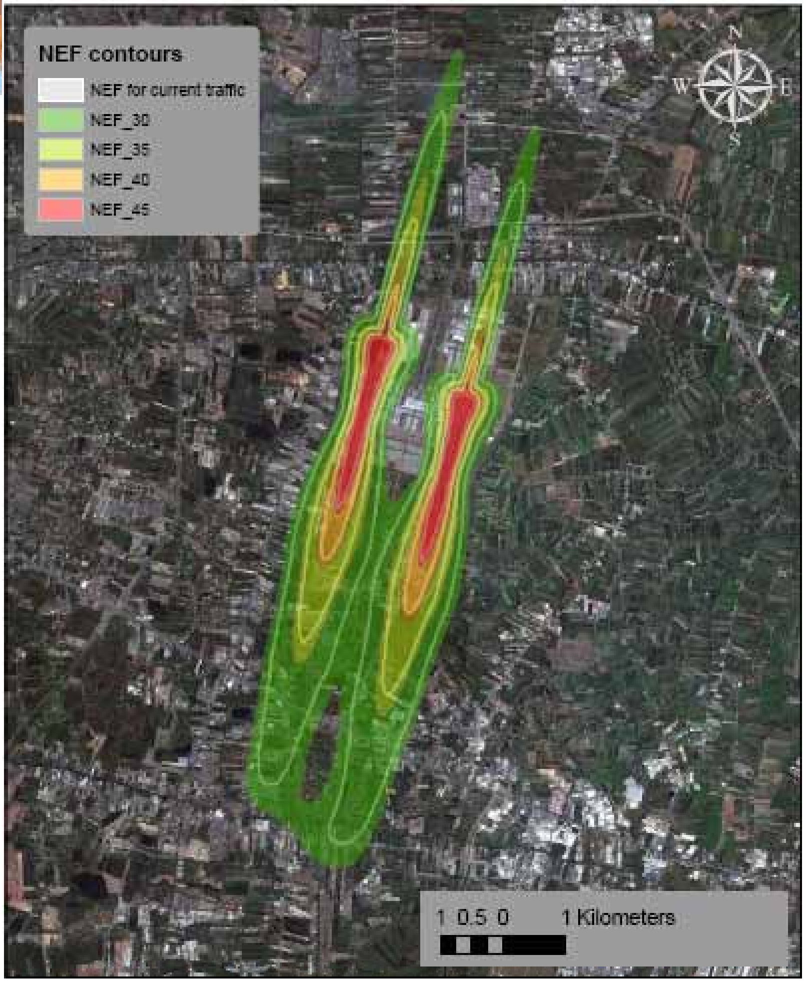


Figure 6 Comparisons of current and 175% traffic in mixed mode: PM

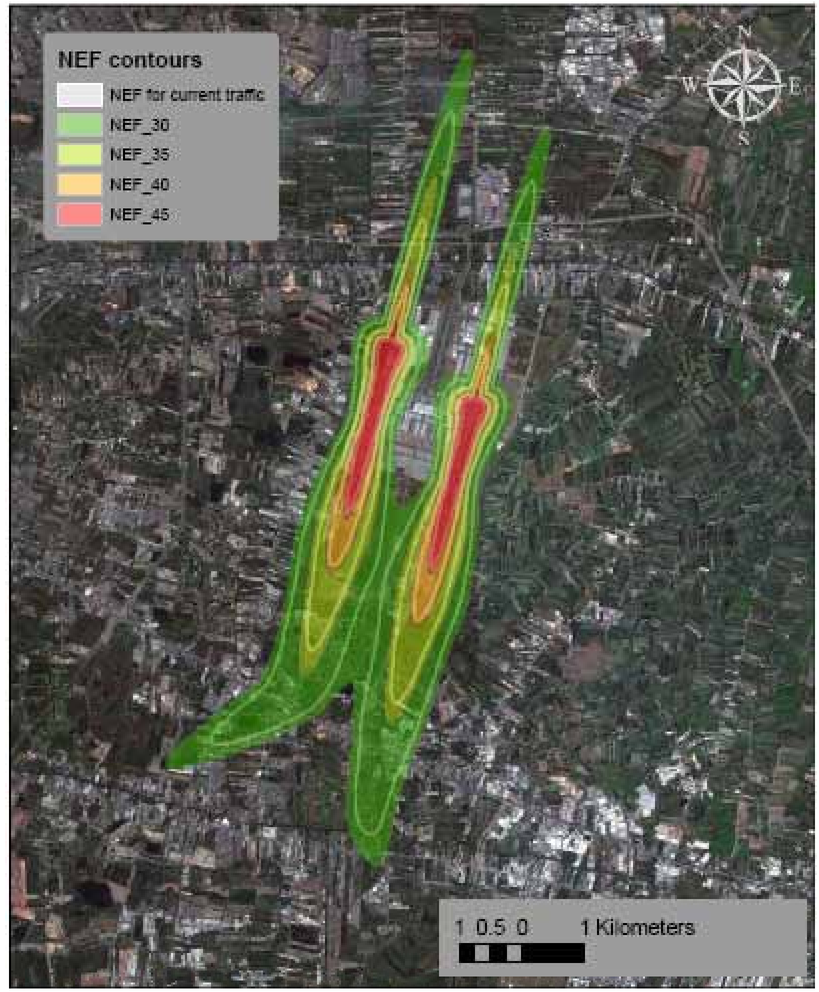


Figure 7 Comparisons of current and 175% traffic in mixed mode: VTBS

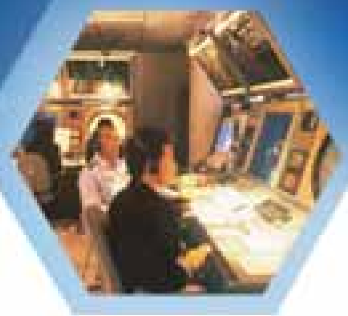
Performance Comparison Summary

Performance Comparison between Point-Merge and Revised Open-STAR

- Capacity:
  - Point-merge can support higher traffic throughputs, both for arrival and departure
  - Point-merge can support upto 175% of the current traffic as compared to 125% by Open-STAR.
- Delay: Point-merge has much better delay performance.
- Workload: Both designs have acceptable controller workload
- Environment:
  - Point-Merge has lower environmental both in terms of noise and carbon emission

ICAO/IATA Expert Recommendations

ICAO/IATA Recommendations



Ref.: AN 11/45.3- ATM40035

DEC 2 2010

Mr. Somchai Chanrod
Director General
Department of Civil Aviation
71 Soi Ngarmdu-Plee
Tungmahamek
Bangkok 10120
Thailand

Dear Mr. Chanrod,

I wish to present you with the outcome of the Go-Team visit to Thailand (25 to 27 August 2010), which was conducted by the International Civil Aviation Organization (ICAO)/International Air Transport Association (IATA) Global Performance Based Navigation Task Force (GPBNTF). The Go-Team performed an assessment on specific working areas and, in agreement with the

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activities with the audience.

I hope that the Go-Team visit was of assistance to Thailand, and I wish you success in the implementation of PBN in your airspace.

Yours sincerely,

Nancy J. Graham
Director
Air Navigation Bureau

Enclosure: Report

cc: President, Aeronautical Radio of Thailand LTD
bcc: ICAORD, Bangkok

ICAO/IATA Recommendations

International Civil Aviation Organization

International Air Transport Association

REPORT
OF THE GLOBAL PERFORMANCE-BASED
NAVIGATION (PBN) TASK FORCE GO-TEAM VISIT TO THAILAND

(25 to 27 August 2010)

GLOBAL PERFORMANCE-BASED
NAVIGATION (PBN) TASK FORCE GO-TEAM VISIT TO THAILAND

Go-Team participants

Inter. Org/Company	Contact Information	Working Area
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ICAO/IATA Recommendations

2.2.2.6 Air Traffic Management

1. *All ATC SOPs should be designed with procedural separation in mind and allow the Air Traffic Controller to use their airspace as efficiently as possible. Letters of Agreements (LOA) should be reached with adjacent States to allow*

> 2. *The existing sectorization should be analysed to determine if the new airspace concept and traffic flows justifies Geographical or Functional ATC sectorization or a combination of both. Complete re-sectorization may be required. A clean-sheet revision on TMA sectorization and TMA entry and exit points is encouraged.*

Bangkok TMA.

4. *Integration of management units between different sectors within Bangkok*

> 4. *Integration of management units between different sectors within Bangkok TMA is highly encouraged. This is to ensure harmonization of ATC procedures and optimization of the use of limited airspace.*

facility using current experienced TMA and ACC Air Traffic Controllers to

5

> 1. *CDO/CCO should be procedurally separated designs that are developed in collaboration with all stakeholders and usable at least 80% of the time. To the extent possible the design should allow the aircraft to descend from cruise and climb to cruise, minimizing ATC radar vectoring or Pilot intervention. Basic design examples, such as Point Merge and Tie-points, as shown in ICAO Doc 9931, Continuous Descent Operations Manual, are highly encouraged.*

2.2.2.7

1. *collaboration with all stakeholders and usable at least 80% of the time. To the extent possible the design should allow the aircraft to descend from cruise and climb to cruise, minimizing ATC radar vectoring or Pilot intervention. Basic design examples, such as Point Merge and Tie-points, as shown in ICAO Doc 9931, Continuous Descent Operations Manual, are highly encouraged.*

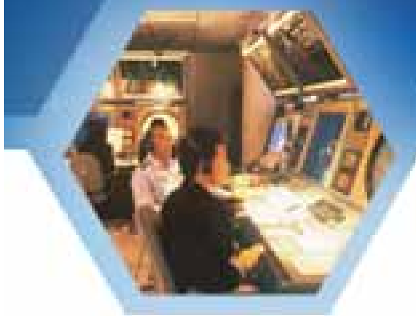
Summary

- **Expected Benefits of Point-Merge Design**
  - Reduce number of route crossings and conflicts in aircraft altitudes
  - Enhancing throughput and capacity
  - Reducing delay
  - Increase predictability of flight path → aircraft track dispersion is well-defined
  - Reduce pilot workloads → using FMS Direct-To instead of RADAR vectoring
  - Reduce communication and frequency block
  - CDO-embedded design
  - Can support single-runway approach through a traffic coordinator
  - Can support independent simultaneous parallel approach → reduce arrival airborne delay

Summary

Potential Challenges of Point-Merge Implementation

- Require larger airspace → However, Bangkok TMA is large enough.
- Reduce some flexibility
- New concept for ATC → Take time and effort to educate and implement
  - Changes in mind-set and work-habit are required.
- Need airspace and sectorization adjustments → may require infrastructure changes, especially on control positions and communication infrastructures



Airspace Sectorization: Baseline

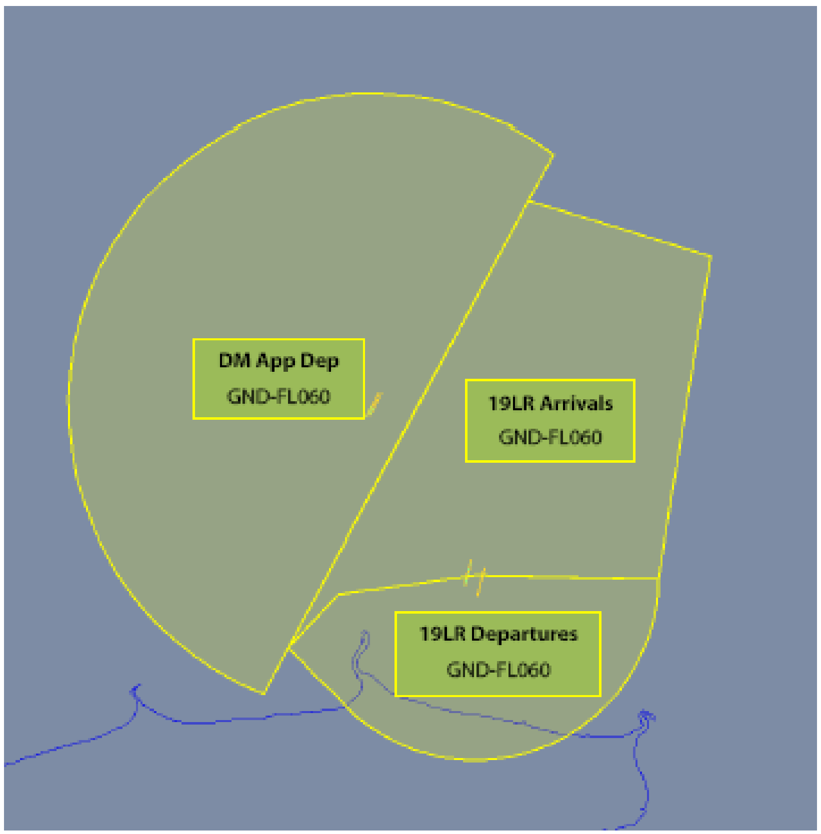


Figure 5 – Baseline Inner Sectors

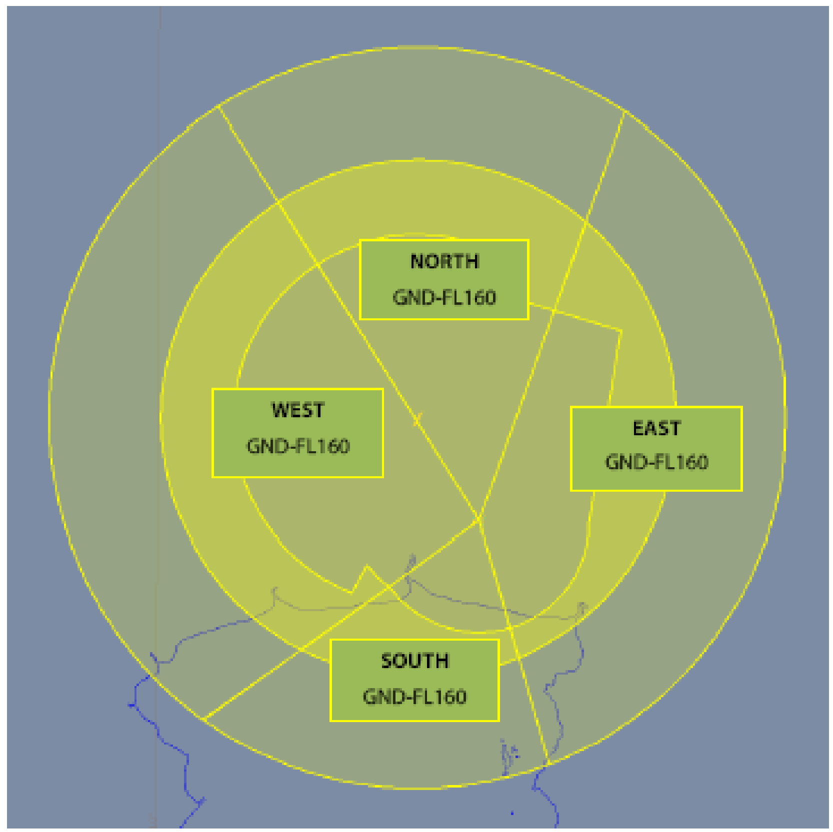


Figure 6 – Baseline Outer Sectors

Airspace Sectorization: Point Merge

Point Merge sector specification differs significantly from the Enhanced Baseline/VTBS design, as the design is based around the configuration of the new SIDs and STARs. Geographic sector structure for Point Merge is shown in the figures below.

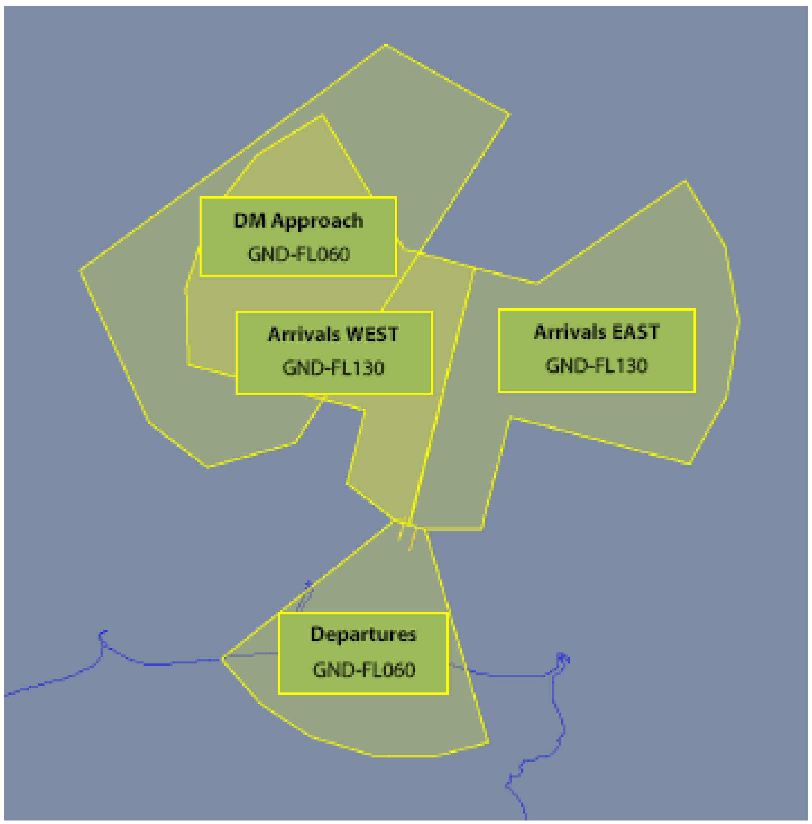


Figure 13 - Point Merge Inner Sectors

Figure 14 - Point Merge Outer Sector


Thank you for your attention.