AGENSI ANGKASA MALAYSIA (MYSA)
KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI (MOSTI)

Enhancing Precision Navigation in Peninsular Malaysia: A Comparative Study of Satellite-Based DGPS and Commercial SBAS Services

(Investigating Navigation Accuracy and Performance)

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UN/ Philippines Workshop on the Applications of Global Navigation Satellite Systems

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- Recommendations & Conclusion
- The Motivations: National SBAS Program

Introduction

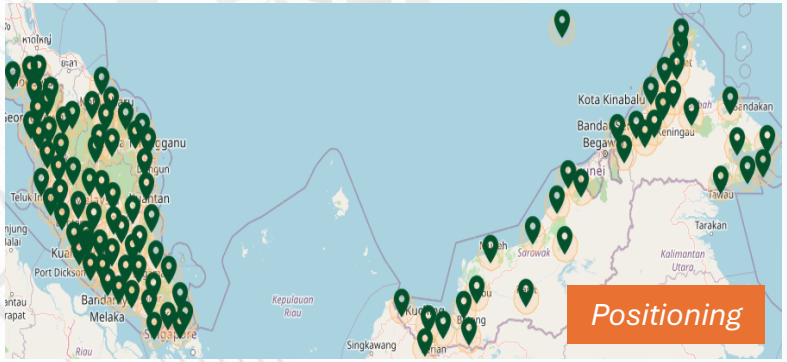
- Overview of Precision Navigation

Introduction

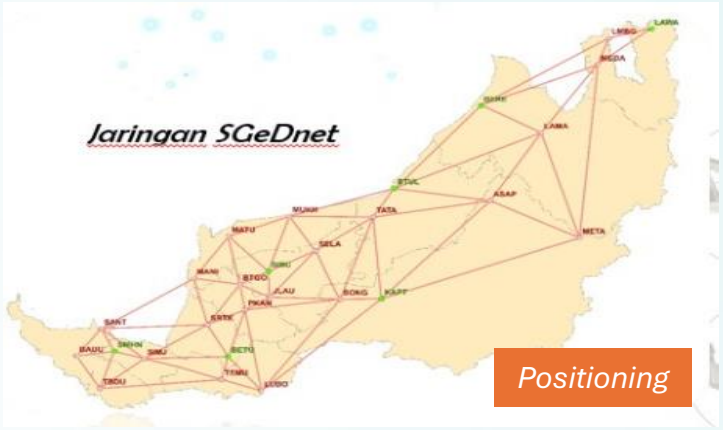
- **GNSS Importance:** Global Navigation Satellite Systems (GNSS) are crucial for Positioning, Navigation, and Timing (PNT), supporting a wide range of activities including navigation, surveying, and meteorology.
- **Economic Impact:** As of 2017, GPS had contributed approximately 215 billion USD to the economy, with its importance and contribution growing over time.
- **Augmentation Techniques:** Accuracy of GPS can be improved through augmentation techniques like Differential GPS (DGPS) or Satellite-Based Augmentation System (SBAS), enhancing accuracy from 5 m to 10 m to sub-meter levels.

GNSS (CORS) Infrastructure in Malaysia

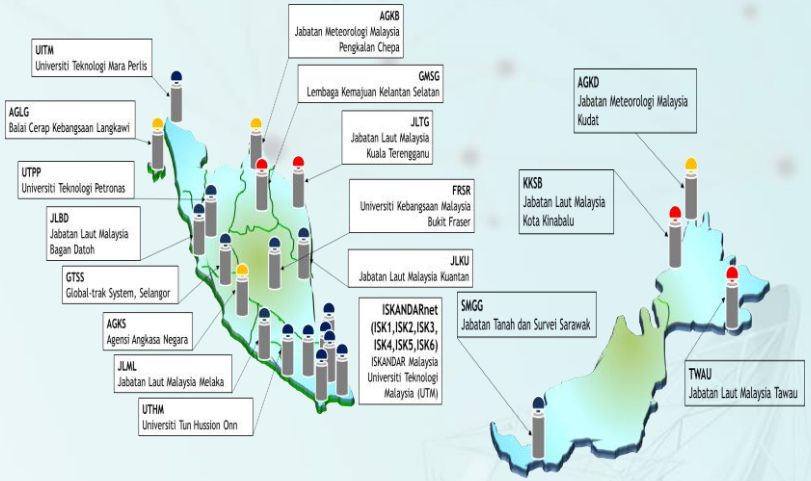
MyRTKnet (JUPEM)



SGeDNet (Sarawak Land & Survey)

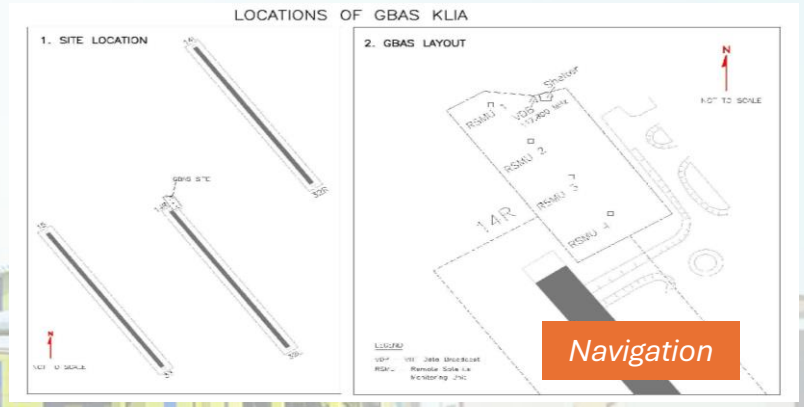


R&D CORS Network



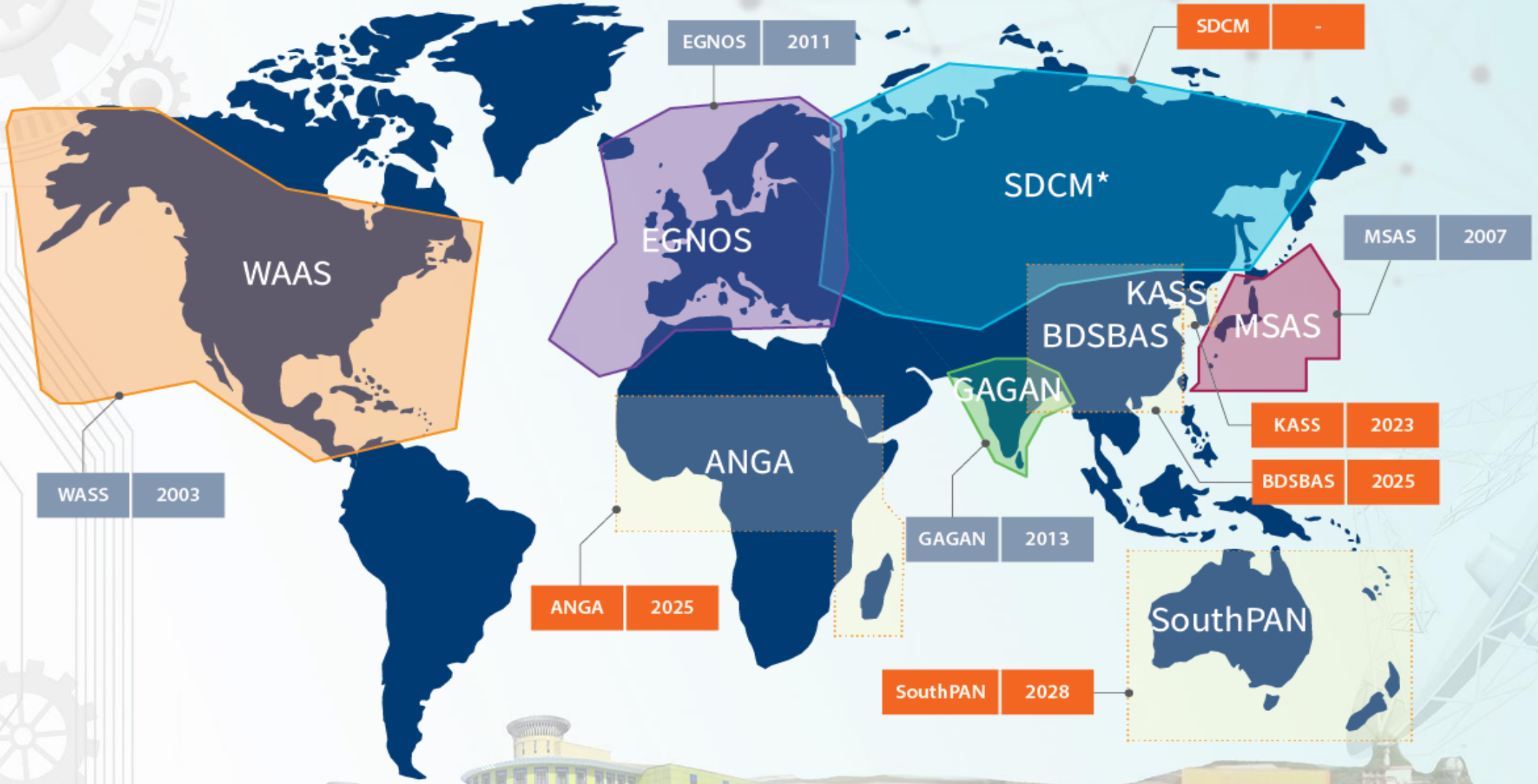
SISPELSAT (Marine Department)

GBAS (CAAM)



Positioning and Navigation

National SBAS Indicative Service Area



Operational/certified for civil aviation

Planning

Under development/definition
*System not yet certified for civil aviation

Commercial SBAS

TerraStar

Horizontal accuracy varies
from 1 m to 10 cm

OmniSTAR

Horizontal accuracy
varies from 1 m to 5 cm

Trimble

Horizontal accuracy varies
from <1 m to < 4cm

Veripos

Horizontal accuracy
varies from <1 m to <5 cm

Fugro

Horizontal accuracy varies
from 1.5 m to 5 cm

C-Nav

Horizontal accuracy
varies from 15 to 8 cm

Study Objectives

- To investigate the accuracy of Satellite Communication DGPS and Commercial SBAS over Peninsular Malaysia.
- To assess the performance of both methods as preliminary steps to enhance precision navigation in Malaysia

Methodology

- Data Collection Approach
- Study Area Description (East Coast of Peninsular Malaysia)
- Instrument Set-up & Data Collection Process

Instrument & Leasing Cost

INTERNET BASE

1 +*1 UNIT R330 HEMISPHERE

* backup

SATELITE COMMUNICATION

1x THURAYA

SIM=RM350 + FOC 10USD

PREPAID=RM250~50USD

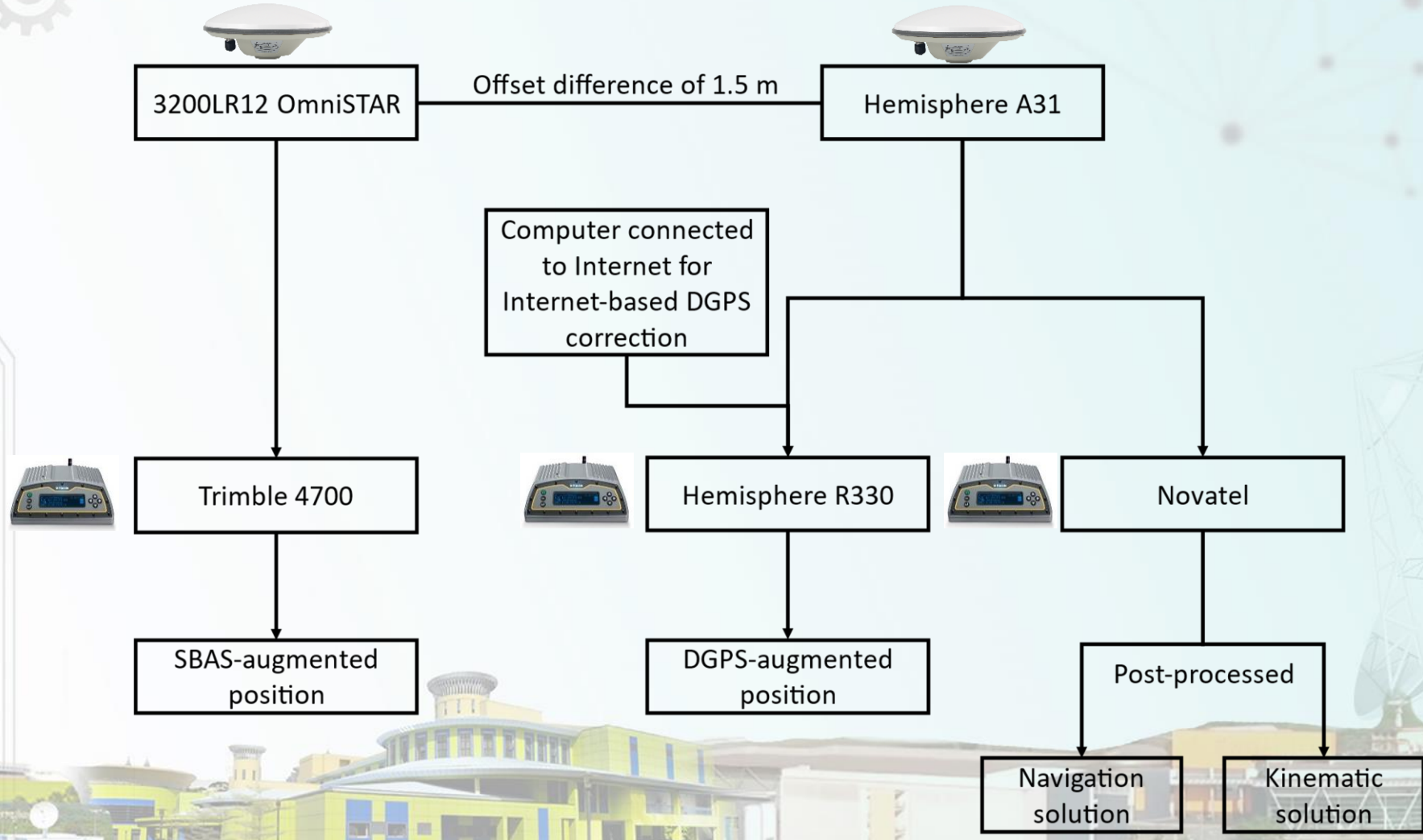
1mb ~ 3usd

SBAS

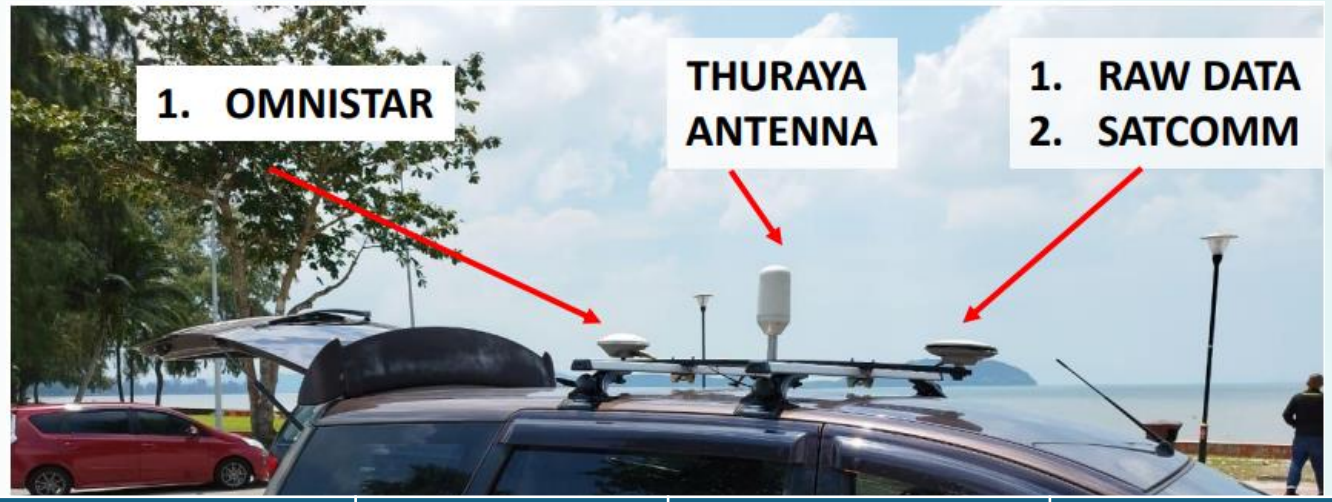
1 x UNIT 3200LR12 OMNISTAR

RM600/day

Schematic Set-up

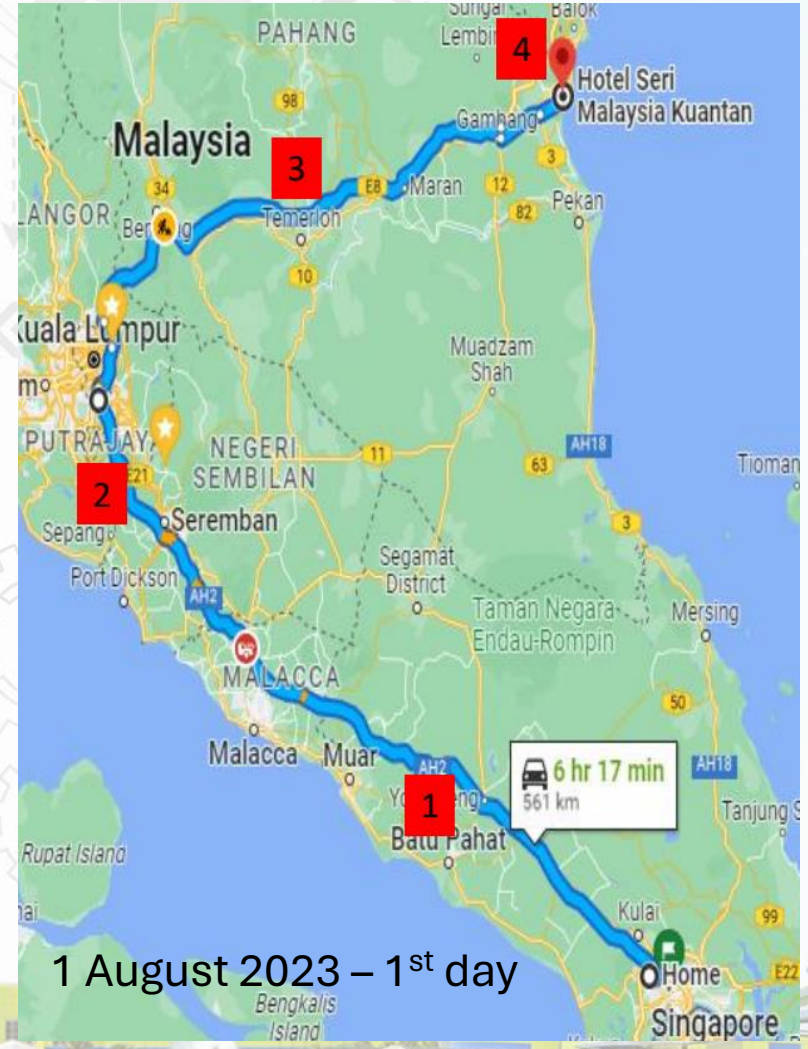


Instrument Set-up



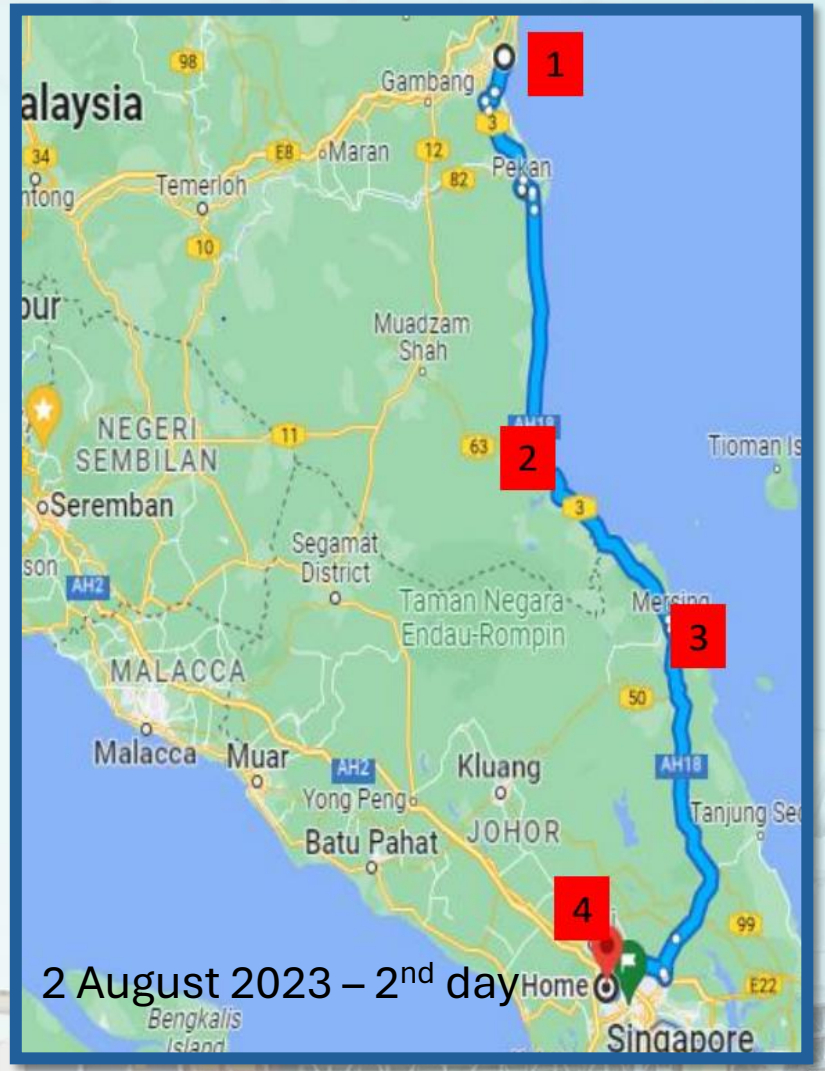
Technique	Name	Datum	Note
Omnistar	OMNI	WGS84	SBAS
Real-time DGPS	SATC	WGS84	Internet-based DGPS / Satellite communication
Raw Kinematic (ISK1)	ISK1	ITRF2014	Raw Data
Raw Kinematic (ISK6)	ISK6	ITRF2014	Raw Data
Raw Kinematic (AGKS)	AGKS	ITRF2014	Raw Data

Study Area



1 August 2023 – 1st day

i. Data were collected for two days.
ii. Internet-based DGPS correction was generated using reference station from NRCnet
   - AGKS - MYSA Banting
   - ISK6 - Tanjung Sedili
   - ISK1 - UTM JB
iii. Satellite Communication (internet) was subscribed through prepaid.
iv. Commercial SBAS equipment and service was leased and subscribed
v. Over 15 hours of GNSS data at 1 Hz, was collected for 2-days



2 August 2023 – 2nd day

Data Processing

i. RTKLib ver 2.4.3 with in-house analysis program to compute the position of solutions.
ii. 4 solutions:
    - *Single point positioning (navigation)*
    - *DGPS*
    - *Commercial SBAS*
    - *Kinematic (highest accuracy)*

Settings	Navigation solution	Kinematic solution
Positioning Mode	Single	Kinematic
Frequencies	Not applicable	L1+L2 Combined
Elevation Mask (°)	15	15
Ionosphere Correction	OFF	Iono-Free LC
Troposphere Correction	OFF	Estimate ZTD
Satellite Ephemeris/ Clock	Broadcast	Broadcast
Integer Ambiguity Resolution	Not applicable	Continuous
Time Format	hh:mm:ss UTC	hh:mm:ss UTC

Results & Discussions

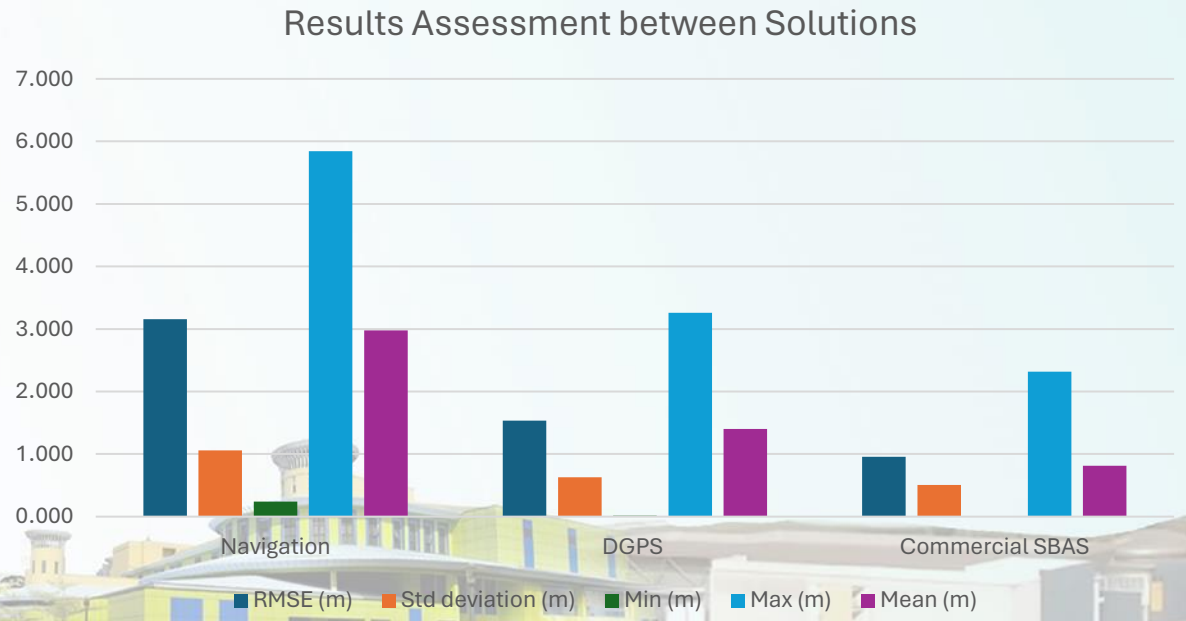
- Accuracy & Performance
- Advantages & Limitations

Navigation Accuracy (1)

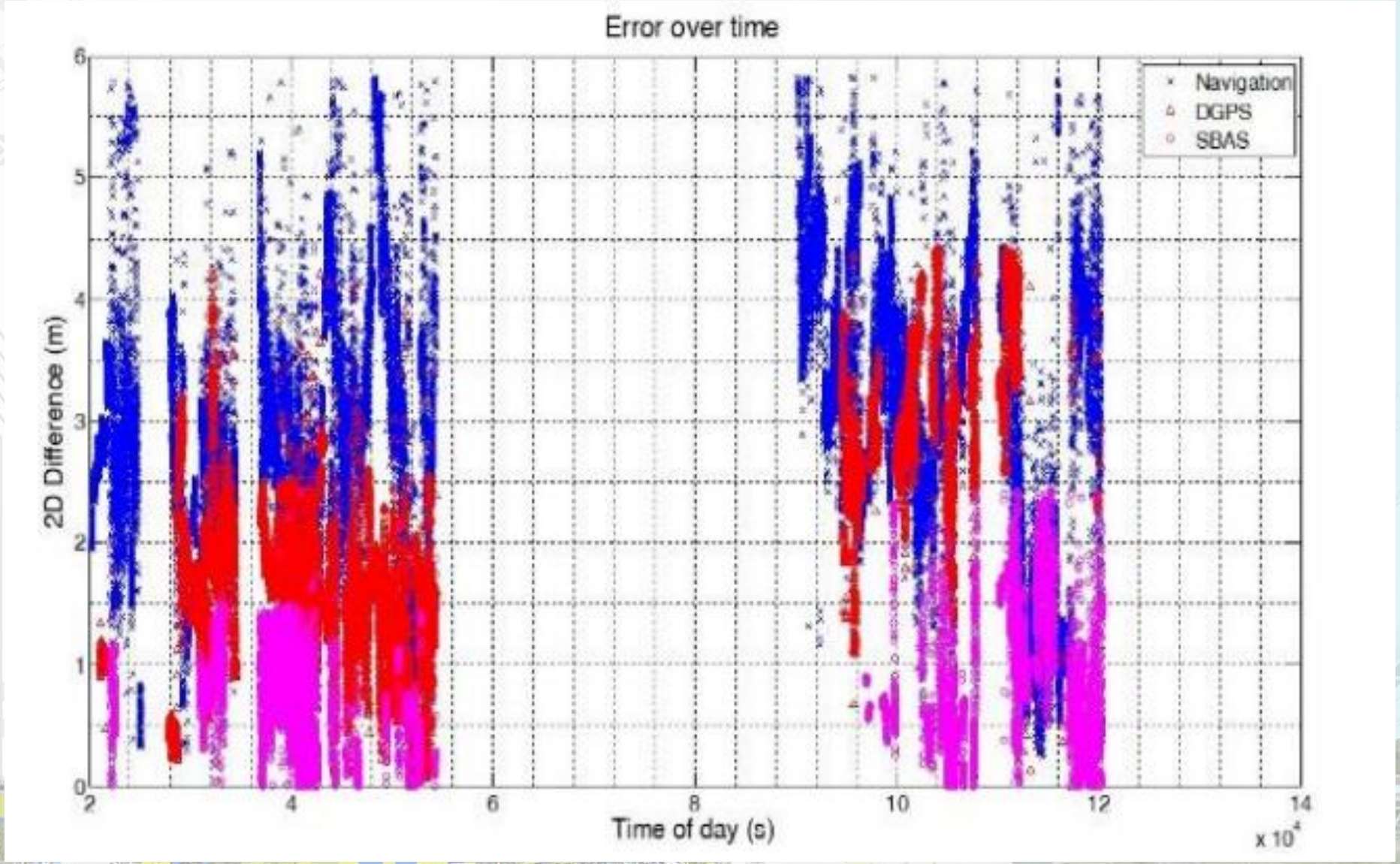
- **Accuracy and Precision Assessment: Root-mean-squared error (RMSE) and standard deviation** were employed to quantify the accuracy and precision of the navigation solution, respectively. These metrics provide insights into the overall quality of the positioning data.
- **Challenges with Kinematic Solution:** In scenarios involving **long distances between reference stations and the receiver**, resolving ambiguity to an integer value for kinematic solutions proved challenging. As a result, **a float kinematic solution was utilized to calculate the accuracy and precision** of the navigation solution under these conditions.
- **Selection of DGPS and SBAS Outputs:** The outputs from the Differential GPS (DGPS) and Satellite-Based Augmentation System (SBAS) solutions varied in terms of accuracy. Therefore, only outputs marked explicitly as **DGPS and SBAS VBS (with the same level of accuracy as DGPS)** were selected for inclusion in this case study. This ensured consistency in the evaluation and comparison of the two augmentation systems.

Navigation Accuracy (2)

Component	Navigation	DPGS	Commercial SBAS
RMSE (m)	**3.159**	**1.536**	**0.955**
Standard Deviation (m)	1.056	0.626	0.504
Min (m)	0.238	0.016	0.000
Max (m)	5.844	3.257	2.317
Mean	2.978	1.403	0.682



Navigation Accuracy (3)



Navigation Performance (1)

- **DGPS Performance:** DGPS shows improved performance when closer to the reference station. The average distance to the reference station in this study was 144.42 km, which is significant.
- **Reference Station Selection:** The manual selection of reference stations did not ensure the use of the nearest station for DGPS correction. An intelligent algorithm for station selection could enhance DGPS accuracy.
- **CORS Network:** The limited availability of reference stations in the NRC-net coverage affects DGPS. Integrating with other networks like MyRTKnet could provide more options.
- **OmniSTAR SBAS & DGPS:** This commercial service requires payment and dedicated receivers, limiting its use to public users who prioritize cost over accuracy. Both DGPS and SBAS are constrained by their communication methods. Internet-based DGPS relies on internet connectivity, which is costly for marine navigation (the data only last for about 4 hours), while SBAS is limited by satellite coverage & availability.

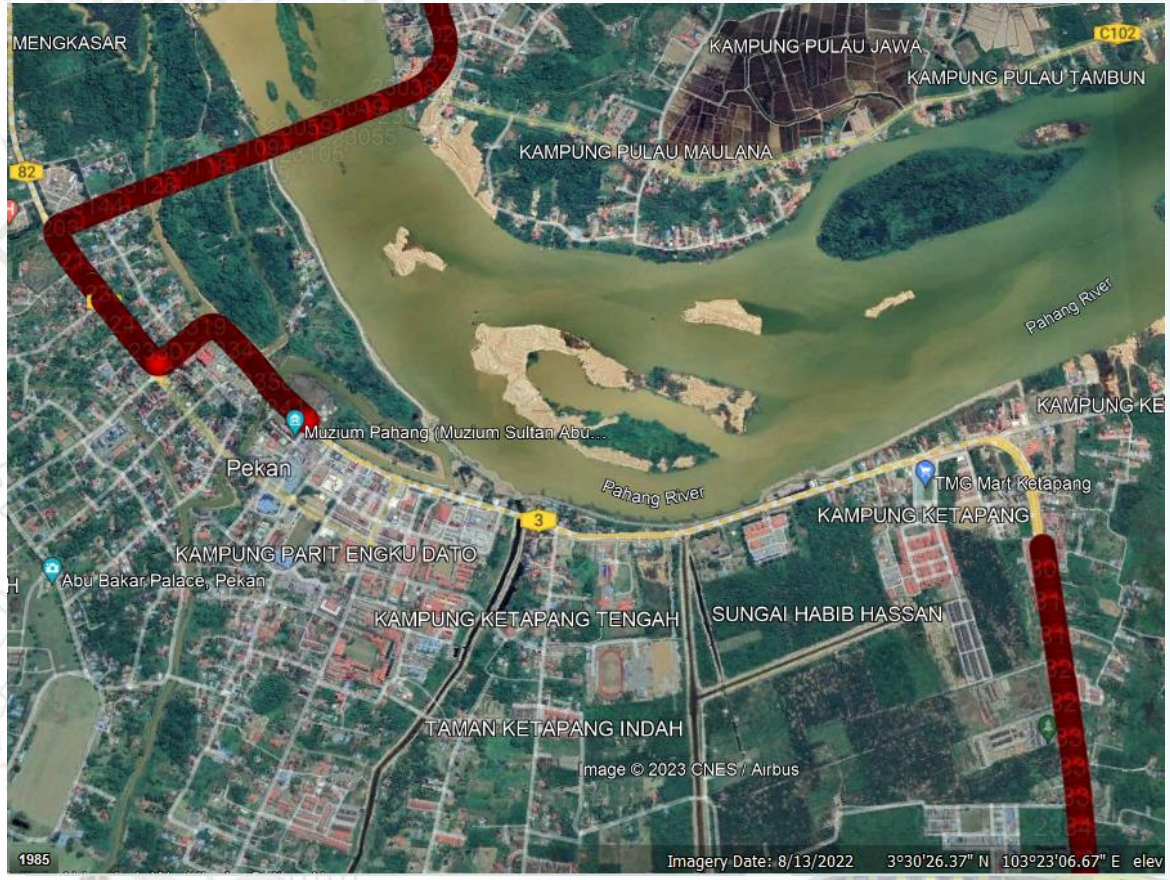
Improvement	DPGS	Commercial SBAS
Accuracy (%)	51.37	69.77
Precision (%)	40.72	52.27

Navigation Performance (2)

Commercial SBAS – 2 satellite outage

Satellite Communication – no data loss

Navigation Performance (3)



Commercial SBAS - Satellite Outage

Recommendations & Conclusion

- Future Research Directions
- Summary of the study

Recommendations

- Implement an intelligent reference station selection algorithm to improve DGPS accuracy.
- Expand the reference stations network to enhance DGPS performance.
- Further research is required to comprehensively evaluate DGPS and SBAS performance in the region, considering diverse environmental and infrastructural factors.

Conclusion

- Both satellite communication **DGPS and SBAS offer much better accuracy and precision** than standard navigation solutions.
- **Limitations** include DGPS performance dependence on reference station distance and internet connectivity, as well as subscription costs for both systems and the need for a dedicated compatible antenna and receiver for SBAS which provide valuable insights on the selection of technique based on applications, accuracy needed and also the allocated budget.
- Findings are **specific to the geographical and environmental conditions** of certain parts of Peninsular Malaysia and may not be directly applicable elsewhere. **Future expansion** of these studies is needed in other areas (urban, rural, heavy canopy area, etc.) to assess performance as a whole.
- This study was used as the **support data for the feasibility study on our national SBAS development** (Malaysia Space Exploration 2030).

The Motivation

- National Space Policy 2030 (DAN2030)
- Malaysian Space Exploration 2030 (MSE2030)
- Space Industry Strategic Plan 2030 (SISP2030)

Malaysian SBAS: Roadmap

Phase 1

INITIAL SETUP / CONCEPT OPERATION

GNSS augmentation system involves establishment of sensor stations, data centre, control centre for signal correction and the dissemination of data correction (Dual Frequency)

Timeline: 2025 – 2026 (12 months)
Cost: -
Collaborators: -

Phase 2

GNSS AUGMENTATION TRIAL (WITH INDUSTRY) – TEST-BED

setup of an uplink station & use of commercial satellite communication (e.g. Inmarsat) to disseminate correction data

Timeline: 2027- 2028 (Development)
2029- 2030 (Test-bed Demo Trial)

Cost: -
Collaborators: -

Phase 3

SBAS DEVELOPMENT

Timeline: 2030 – 2035 (5 years)
Cost: -
Collaborators: -

Activities towards SBAS Development and Implementation

No	Item	Year
1	**Feasibility Study** *- SBAS Preliminary Study Report: Technical, Market and Financial* *- Initial POC on GNSS/SBAS Navigation Accuracy & Performance*	2023
2	**i. Consideration Paper for JANGKA Technical Committee (Technology, Research, & Innovation):** • Implementation and Development Plan of SBAS to enhance navigation efficiency and safety within the country **ii. Proof of Concept (POC) Research Activities:** • Assess the reliability and effectiveness of SBAS in the context of national navigation and the impact on various navigation applications, including aviation, maritime, land, and others **iii. Engagement Session with Government Agencies, Academic Institutions, and Industries:** • Presentation of POC research findings to stakeholders. • Distribution of user surveys and feedback collection. • Obtain input and perspectives from government agencies, academic institutions, and industries regarding SBAS implementation and next steps.	2024
3	**Development Budget Proposals**	2025

STRUCTURE OF NATIONAL SPACE POLICY 2030

Capitalize Space Sector Towards Sovereignty and Sustainability High-Income Nation

DSTIN

VISION: Space sector as a strategic contributor towards Malaysia's sovereignty and competitiveness

MISION: Fostering national capability in the space sector to support economic development and the advancement of knowledge for soceital well being

Goals

Increased Productivity	Strengthen technology, infrastructure and human resources	Optimally utilize space capabilities	Conformity to international instruments and treaties

THRUST 1	THRUST 2	THRUST 3	THRUST 4	THRUST 5
Strengthen Governance	Significant technology, infrastructure and applications	Drive development and build up expertise	Contribute to economy and welfare	Increase international relation and cooperation

Objectives

To have a stance on space sector	To coordinate activities	To assure access to space	To determine way forward

Malaysian Aerospace Blueprint 2030

THRUST 1

SHORT TERM

- ✓ 1 DAN2030 Action Plan
- ✓ 1 Malaysian Space Board Act 2022
- ❑ 1 Malaysian Space Board Regulations
- ✓ 1 Malaysian Space Board

MID-TERM

- ❖ 1 Space Technology Cluster in MPN
- ❖ 1 National Space Related Facility and Infrastructure Registry System and Database

92 KPI

SHORT TERM (2023) 17

MID-TERM (2024 – 2026) 43

LONG TERM (2027 – 2030) 32

THRUST 2

SHORT TERM

- ✓ 1 Special Fund for R, D, C & I
- ✓ 1 AI based Product

MID-TERM

- ❑ 1 RS Satellite
- ❑ 1 Space Launcher Site
- ❖ 4 Sensor System (Multispectral, Hyperspectral, Radar & LiDAR)
- ❖ 1 Space Weather Information and Prediction System
- ❖ 1 Light Pollution Guidelines
- ❖ 3 AI based Product
- ❑ 1 Space City
- ❖ 3 Space Technology Product
- ❑ 1 Product Commercialization Guidelines
- ❖ 1 Space Tech Status Industry Guidelines
- ❖ The launch of Malaysia's Space Tech Program
- ❖ 1 Type of Incentive – Space Tech
- ❖ Malaysian Standard for Space Technology
- ❑ 3 Upgrading Space Technology Facilities

LONG TERM

- ❖ 1 Micro Satellite Constellation
- ❖ 1 Communication Satellite
- ❖ 1 LEO Communications Satellite Transponder
- ❖ 1 Launcher Facility
- ❖ 1 Rocket Launcher
- ❖ 2 Optical Sensors (Meteorology and infrared/thermal)
- ❖ 2 Space Weather Forecasting Model
- ❖ 1 Observatory 2.0 NEO
- ❖ 1 Space/Cosmic Radiation Testing
- ❖ 6 AI based Product
- ❖ 5 Space Technology Product
- ❖ 20 Space Tech Industry
- ❖ **1 SBAS System**
- ❖ 1 Ground Sensor Terminal
- ❖ 1 Testing Facility - Small/Nano Satellites

THRUST 3

SHORT TERM

- ✓ 1 Seminar/Conference
- ✓ 1 Expertise Development Program
- ✓ 1 Space S&T Expert Committee
- ✓ 15 Expert
- ✓ 70 Organized Programs
- ✓ 30 Local Students and Researchers
- ✓ 3 Awareness program

MID-TERM

- ❖ 1 Plan for R, D, C and I
- ❖ 1 Database for R,D,C & I
- ❖ 1 Publication Editorial Committee
- ❖ 1 Space Journal
- ❖ 3 Annual Space Technology Seminar/Conference
- ❖ 1 Improved Space Syllabus
- ❖ 1 HRD Plan
- ❖ 3 Expertise Development Program
- ❖ 45 Expert
- ❖ 3 Accreditation
- ❖ 150 Organized Programs
- ❖ 90 Local Students and Researchers
- ❖ 1 Impact Study Report
- ❖ 10 Awareness program

LONG TERM

- ❖ 4 Seminar/Conference
- ❖ 4 Expertise Development Program
- ❖ 60 Expert
- ❖ 7 Accreditation
- ❖ 200 Organized Programs
- ❖ 120 Local Students and Researchers
- ❖ 1 Impact Study Report
- ❖ 15 Awareness program

THRUST 4

SHORT TERM

- ✓ 1 Space Industry Ecosystem Study Report
- ✓ 1 Space Industry Strategic Plan 2030
- ✓ 5 New Space Technology Application System

MID-TERM

- ❖ 1 Space Sector Account - DOSM
- ❖ 1 Tax Exemption Incentive
- ❖ 1 Foreign Investment Policy/Improved Policy
- ❖ 20% Service Increase
- ❑ 1 Marketing Plan
- ❖ 15 New Space Technology Application System
- ❖ 1 NEO Development Study Report

LONG TERM

- ❖ 1 SISP2030 Achievement Report
- ❖ 40% Service Increase
- ❖ 1 Marketing Plan Effectiveness Evaluation Report
- ❖ 20 New Space Technology Application System
- ❖ 1 Space-based Disaster Management Plan
- ❖ 1 NEO Characterization Model

THRUST 5

SHORT TERM

- ✓ 1 International MoU was signed

MID-TERM

- ❑ 2 International Outer Space Treaty Ratified
- ❑ 1 Space Law Referral Center
- ❖ Malaysia appointed as European Space Agency (ESA) Observer
- ❖ 3 New Organizations
- ❖ 1 International MoU was signed
- ❖ 1 Organized/Participated in International Expos/Conferences

LONG TERM

- ❖ 3 International Outer Space Treaty Ratified
- ❖ 2 International MoU was signed
- ❖ 1 Space Exploration Mission

STATUS:

- ✓ Done
- ❑ In-Progress
- ❖ Will Be Implemented

IMPLEMENTATION OF

THE MALAYSIAN SPACE INDUSTRY

STAKEHOLDERS

MOSTI
MOF
MITI MALAYSIA
MOT MINISTRY OF TRANSPORT
MINDEF
Ministry of Higher Education (MOHE)
EPU
TDA Technology Depository Agency
SMECORP
MATRADE
NAICO MALAYSIA
MIDA Malaysian Investment Development Authority
JUPEM

POLICYMAKERS & GOVERNANCE

KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI

MALAYSIA SPACE BOARD

KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI
AGENSI ANGKASA MALAYSIA

UPSTREAM

Space-related Manufacturing

Orbital Space (M) Sdn Bhd
TANAHAIR TECHNOLOGIES
SPACEIN
INDEPENDENCE X AEROSPACE

Spacecraft Launching

SPACEIN
INDEPENDENCE X AEROSPACE

Ground Equipment

STEALTH SOLUTIONS
... Zone Systems ...
tsgn
INFINITUS TECHNOLOGY
BiNa

MIDSTREAM

Satellite Operators

measat

DOWNSTREAM

Earth Observation

Geo Sense
GEO SPATIAL SOLUTION
RS&GIS
JPSurveys
JUKUPRO
MNJ
GTS
Global-trak Systems
TOPCON
RG
DR. NIK & ASSOCIATES SDN. BHD.

Earth Observation & Navigation

spatialworks
GEO NEO
GPS LANDS (M) SDN BHD
SKY SHINE
MTM PRECISION
SURDATA SDN BHD
TOPACE
Technologies
GEOSPATIAL media + communications
INTEC

Navigation

PURPLE
my spatial
mygps
GOPHERS GPS Navigation Systems
mycopter AVIATION SERVICES
GP SEARCH
NETSTAR
GROUP
Surmap Sdn Bhd
GPStech SOLUTIONS
skytrack
K-One innovate
GPS TRACKER
BANDWORK
KENSAINS SDN BERHAD

VSAT Communication

thetaedge
NUMIX
ScopeTel
BAYCOM
SKYSAT
PRIVASAT

RESEARCH, TRAINING AND EDUCATION INSTITUTIONS

Universiti Kebangsaan Malaysia — The National University of Malaysia
Universiti Malaya
Universiti Teknologi MARA
UPM Universiti Putra Malaysia
UTM Universiti Teknologi Malaysia
USM Universiti Sains Malaysia

Thank you