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REPORT
ON
WEATHER SATELLITE LAUNCH

Submitted in partial fulfillment of requirements for the award of 7th Sem of

BACHELOR OF ENGINEERING

IN

COMPUTER SCIENCE AND ENGINEERING

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CHAPTER 1

INTRODUCTION

Satellites have revolutionized the way we observe, understand, and predict changes in the Earth's atmosphere and environment. Among the many satellites operating around the wor ld,**Himawari-9**, launched by the**Japan Meteorological Agency (JMA)**, stands out as one of the most advanced real-time weather observation satellites in operation today. Positioned in a **geostationary orbit** approximately 35,786 kilometers above Earth at **140.7° East longitude**, Himawari-9 continuously monitors the **Asia–Pacific region**, providing vital data for weather forecasting, disaster management, and environmental monitoring.

Launched on **November 2, 2016**, from the Tanegashima Space Center using an **H-IIA launch vehicle**, Himawari-9 is part of the **next-generation Himawari series**, which includes its twin satellite, **Himawari-8**. Together, they ensure uninterrupted, high-resolution, and real-time observation of Earth's atmosphere. Himawari-9 is equipped with the **Advanced Himawari Imager (AHI)**, a state-of-the-art instrument that captures images across **16 spectral bands**, ranging from visible to infrared wavelengths. This enables the satellite to observe weather patterns, cloud formations, sea surface temperatures, aerosols, and even volcanic ash with remarkable accuracy.

One of the key features of Himawari-9 is its **real-time imaging capability**. It provides **full-disk images every 10 minutes**, and for regions such as Japan and surrounding areas, it captures images every **2.5 minutes**. This rapid data update rate is essential for tracking fast-evolving weather events such as typhoons, thunderstorms, and heavy rainfall. The data collected by Himawari-9 is distributed through the **HimawariCast** system, which allows meteorological agencies, researchers, and disaster management authorities across the Asia-Pacific to access information almost instantaneously.

Himawari-9 plays a crucial role in **disaster prediction and climate studies**, especially in regions prone to extreme weather conditions like tropical cyclones, floods, and volcanic eruptions. The satellite's continuous stream of high-quality data supports aviation safety, maritime navigation, agriculture, and environmental protection. Furthermore, its contribution to **global climate monitoring networks** makes it a cornerstone for international collaboration in atmospheric science.

CHAPTER 2

PROBLEM ANALYSIS

In recent years, the frequency and intensity of natural disasters such as **cyclones, floods, wildfires, and droughts** have significantly increased due to climate change and environmental degradation. These disasters often strike with little warning, resulting in **loss of lives, destruction of property, and economic setbacks**, especially in countries located in the **Asia–Pacific region**, which is one of the most disaster-prone areas in the world. Accurate, real-time monitoring and forecasting of weather events have therefore become a critical global need.

Before the deployment of advanced satellites like **Himawari-9**, weather forecasting relied on **limited observational data** from older satellites that offered **low spatial and temporal resolution**. This meant that meteorological observations were updated only every 30 minutes to an hour, making it difficult to track rapidly changing weather phenomena such as typhoons, thunderstorms, or volcanic ash clouds. Consequently, **early warning systems** often failed to provide timely alerts, resulting in inadequate disaster preparedness and delayed emergency response.

Furthermore, earlier satellites lacked the capability to provide **multi-spectral imagery**, restricting the ability to analyze atmospheric parameters such as **cloud type, temperature, water vapor content, and aerosol concentration**. This limited the accuracy of both short-term weather forecasts and long-term climate assessments. In addition, many developing nations in Asia had limited access to high-quality meteorological data, which further weakened regional cooperation and disaster mitigation efforts.

To address these issues, Japan's **Himawari series of geostationary satellites** was developed to deliver **continuous, high-resolution, real-time data** to improve weather prediction and environmental monitoring. The **Himawari-9 satellite** was specifically designed to overcome the shortcomings of its predecessors by providing **imagery every 10 minutes** for the entire hemisphere and every **2.5 minutes** for target areas. Its **Advanced Himawari Imager (AHI)** allows for the detection of even subtle atmospheric changes across **16 spectral bands**, thereby enabling early identification of severe weather conditions.

CHAPTER 3

MISSION OBJECTIVES

The **Himawari-9 satellite** was developed and launched by the **Japan Meteorological Agency (JMA)** with the primary goal of enhancing **real-time meteorological observation and environmental monitoring** over the Asia–Pacific region. Its mission supports not only Japan's national weather forecasting capabilities but also contributes significantly to global climate and disaster management systems. The objectives of the Himawari-9 mission are multi-dimensional, addressing both immediate operational needs and long-term scientific goals.

1. Continuous Real-Time Weather Observation

The foremost objective of Himawari-9 is to provide **continuous and real-time monitoring** of weather systems across the Asia–Pacific region. By capturing high-resolution images every **10 minutes** (and every **2.5 minutes** for target areas), the satellite ensures that meteorologists receive up-to-date information about evolving atmospheric conditions. This capability is crucial for detecting and tracking **typhoons, storms, and cloud formations** that develop rapidly.

2. Improved Weather Forecasting and Early Warning

Himawari-9 plays a key role in **improving the accuracy of weather forecasts** and **strengthening early warning systems**. The real-time data collected allows meteorologists to predict severe weather events such as **tropical cyclones, heavy rainfall, thunderstorms, and fog formation** with higher precision. This enhances the ability of governments and disaster management agencies to issue timely alerts and minimize loss of life and property.

3. Environmental and Climate Monitoring

Another major mission objective is to support **environmental observation** and **climate research**. Himawari-9 monitors long-term changes in atmospheric parameters such as **sea surface temperature, humidity, and aerosol levels**. This data contributes to studies on **global warming, monsoon behavior, and air pollution**, providing scientists with valuable insights into Earth's changing climate system.

4. Disaster Risk Reduction and Management

Himawari-9 assists in **disaster preparedness and response** by providing near real-time imagery of events such as **typhoons, volcanic eruptions, forest fires, and floods**. The satellite's rapid imaging capability enables authorities to monitor the development, intensity, and movement of such disasters, allowing for effective evacuation planning and emergency coordination.

5. Support for Aviation and Marine Safety

The satellite provides critical weather information for **aviation and maritime operations**, including cloud motion, turbulence detection, and sea surface temperature data. These insights help ensure **safe navigation and flight operations** across the Asia-Pacific region.

6. International Data Sharing and Collaboration

Himawari-9 contributes to **global meteorological cooperation** through the **World Meteorological Organization (WMO)** by sharing data with neighboring countries. This promotes regional collaboration in weather forecasting and disaster management.

CHAPTER 4

PAYLOAD AND INSTRUMENTS

The Himawari-9 satellite is equipped with one of the most advanced Earth-observing payload systems designed for continuous meteorological and environmental monitoring. Its main instrument, the Advanced Himawari Imager (AHI), enables high-resolution, multi-spectral imaging that supports real-time weather forecasting, climate research, and disaster monitoring. The satellite's payload and support systems work together to capture, process, and transmit critical atmospheric and surface data across the Asia-Pacific region.

1. Advanced Himawari Imager (AHI)

The AHI is the primary payload onboard Himawari-9. It is an optical imaging radiometer designed to capture visible, near-infrared, and infrared images of the Earth's surface and atmosphere. The AHI is similar in design to the Advanced Baseline Imager (ABI) used on the U.S. GOES-R series but is specifically optimized for the Asia-Pacific region.

Key Features of AHI:

- Spectral Bands: 16 channels ranging from visible (0.47 µm) to infrared (13.3 µm).
- Spatial Resolution:
  - 0.5 km for visible bands.
  - 1–2 km for infrared bands.
- Temporal Resolution:
  - Full-disk imagery every 10 minutes.
  - Target area imagery every 2.5 minutes (e.g., Japan and surrounding regions).
- Scan Capability: The instrument uses a two-axis scanning mirror system, allowing it to image the full Earth disk as seen from geostationary orbit.

Functions and Applications:

- Cloud detection and classification: Identifies cloud type, height, and thickness.
- Typhoon and storm tracking: Monitors formation, direction, and intensity in near real-time.
- Sea and land surface temperature measurement: Supports marine and agricultural analysis.
- Aerosol and volcanic ash detection: Provides data for air quality and aviation safety.
- Shortwave and longwave radiation monitoring: Helps in climate and energy balance studies.

2. Data Collection and Transmission System

Himawari-9 uses an advanced data relay and broadcast system to deliver real-time imagery and meteorological data to ground stations through the HimawariCast service.

- Transmission Band: L-band digital broadcast.
- Ground Segment: Managed by the Japan Meteorological Agency (JMA) with data relayed to international meteorological centers.
- Data Format: Himawari Standard Data (HSD), compatible with WMO data systems. This system ensures that weather data is received by national and regional agencies within minutes of observation, enabling rapid forecasting and disaster response.

3. Support Instruments and Systems

Although AHI is the main instrument, Himawari-9 also carries housekeeping and engineering subsystems to ensure mission performance:

- Star trackers and gyroscopes: For precise attitude and orbit control.
- Thermal control system: Maintains temperature stability for imaging sensors.
- Onboard data processor: Handles image correction, calibration, and compression before

transmission.

- Solar array and batteries: Supply approximately 2.6 kW of power for continuous operation.

4. Overall Payload Performance

The payload system of Himawari-9 enables near-continuous Earth observation with exceptional clarity and reliability. The combination of multi-spectral imaging, high temporal frequency, and real-time data relay allows for unprecedented accuracy in monitoring weather dynamics, environmental changes, and natural disasters.

CHAPTER 5
DATA AND COMMUNICATION SYSTEM

1. Data Acquisition

The primary instrument, the **Advanced Himawari Imager (AHI)**, continuously scans the full disk of the Earth from its geostationary orbit at **140.7° East longitude**.

Observation Frequency:

- Full-disk imagery every **10 minutes**.
- Targeted regional imagery every **2.5 minutes**.

- The data collected includes **visible, infrared, and near-infrared spectral bands**, which provide detailed information about **cloud formation, sea surface temperature, aerosol levels, and land conditions**.
- The raw data is first processed and **compressed onboard** to reduce transmission time and bandwidth usage.

2. Data Transmission

Himawari-9 employs an advanced **L-band communication system** for real-time data downlink to ground stations. The satellite transmits data using a **digital broadcast system** known as **HimawariCast**, which ensures rapid dissemination to meteorological agencies and users across the Asia-Pacific region.

Key Features:

- **Transmission Band:** L-band digital broadcast (1.68–1.7 GHz).
- **Downlink Rate:** Approximately **18 Mbps** for high-resolution data.
- **Data Latency:** Typically under **3 minutes** after observation.
- **Communication Link:** Utilizes a stable geostationary relay path for uninterrupted signal transmission.

This high-speed transmission system ensures that updated images and weather data are continuously available to operational weather centers, disaster management authorities, and research institutions.

3. Ground Segment and Data Distribution

The ground segment of Himawari-9 is managed by the **Japan Meteorological Agency (JMA)**, which operates multiple ground receiving stations in Japan. These stations receive, decode, and process data into the **Himawari Standard Data (HSD)** format for distribution.

The processed data is distributed via:

- **HimawariCast:** Satellite broadcast for real-time users (e.g., national meteorological services).
- **JMA's Internet Data Service (JAXA/JMA Portal):** For researchers and international agencies.
- **WMO Global Telecommunication System (GTS):** For global weather data exchange.

These services ensure open access and international data sharing under the **World Meteorological Organization (WMO)** framework.

4. Data Processing and Quality Control

Upon reception, data undergoes **radiometric and geometric correction**, calibration, and validation to ensure high accuracy. The processing pipeline includes:

- **Image correction** for sensor distortions and alignment.
- **Spectral calibration** for accurate radiance measurements.

5. Reliability and Redundancy
To ensure uninterrupted data flow, Himawari-9 operates in coordination with **Himawari-8**, providing **redundant coverage** in case of system failure or maintenance. Both satellites can back each other up, guaranteeing continuous service availability throughout the Asia-Pacific region.

CHAPTER 6:

APPLICATIONS

1. Weather Forecasting and Analysis

One of the most significant real-time applications of Himawari-9 is in operational weather forecasting.

- The Advanced Himawari Imager (AHI) provides near-continuous monitoring of cloud formation, movement, and atmospheric conditions.
- Meteorologists use this data to predict rainfall, thunderstorms, typhoons, and fog with higher accuracy.
- The satellite's rapid imaging cycle (every 10 minutes globally and every 2.5 minutes regionally) allows forecasters to observe fast-changing weather systems in real time, significantly improving short-term and nowcasting capabilities.

  For instance, during typhoon season, Himawari-9's imagery enables early detection and accurate tracking of storm paths, which helps in issuing timely warnings and reducing damage.

2. Disaster Monitoring and Management

Himawari-9 provides crucial support in disaster management, particularly for natural events such as:

- Tropical cyclones and typhoons – tracking their formation, movement, and intensity.
- Floods and heavy rainfall – monitoring cloud density and precipitation potential.
- Volcanic eruptions and ash plumes – detecting ash dispersion that affects aviation safety.
- Forest fires and heatwaves – identifying thermal anomalies using infrared bands.
- This real-time monitoring capability allows governments and emergency response teams to plan evacuations, allocate resources, and coordinate rescue operations effectively.

3. Aviation and Maritime Operations

Himawari-9 data is extensively used in aviation weather services and marine navigation systems.

- It provides cloud-top temperature, turbulence, and wind information, enhancing flight safety and route planning.
- For maritime sectors, it delivers sea surface temperature, wind speed, and storm tracking data, ensuring the safety of ships and offshore operations. These real-time datasets help reduce flight delays, avoid hazardous routes, and improve overall transportation efficiency.

4. Agriculture and Environmental Monitoring

In the agricultural sector, Himawari-9 assists in crop monitoring, drought detection, and irrigation management.

- The satellite measures surface temperature and soil moisture levels, helping farmers make informed decisions.
- Environmental agencies use the data to track air pollution, dust storms, and aerosol concentrations, enabling better management of public health and environmental safety.

5. Climate Research and Long-Term Observation

Beyond immediate forecasting, Himawari-9 contributes significantly to climate research by providing continuous datasets for studying:

- Global warming trends,
- Oceanic temperature variations,
- Seasonal monsoon behavior, and

6. International Data Sharing and Collaboration

Through the HimawariCast system and the World Meteorological Organization (WMO) network, Himawari-9's real-time data is shared globally with weather agencies, research institutions, and universities. This promotes international cooperation in weather prediction and enhances the collective ability to respond to global climatic events.

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CHAPTER 7

ADVANTAGES AND DISADVANTAGES

7.1 ADVANTAGES:

1. High Temporal Resolution (Real-Time Monitoring)

One of the greatest advantages of Himawari-9 is its ability to provide **real-time weather imagery every 10 minutes** for the full Earth disk and **every 2.5 minutes** for specific regions such as Japan and the Asia-Pacific. This frequent update rate allows meteorologists to closely monitor fast-evolving weather phenomena like **typhoons, thunderstorms, and volcanic eruptions**, enabling timely forecasts and warnings.

2. High Spatial and Spectral Resolution

The satellite's **Advanced Himawari Imager (AHI)** captures data in **16 spectral bands**, including visible, near-infrared, and infrared wavelengths, at resolutions of **0.5 to 2 kilometers**. This enables precise observation of clouds, land, and ocean surfaces. Such high-resolution imagery helps in identifying small-scale atmospheric changes that were previously undetectable with older satellites.

3. Enhanced Weather Forecasting Accuracy

Himawari-9's continuous data stream significantly improves **short-term (nowcasting)** and **medium-range forecasting**. The satellite provides detailed measurements of **cloud movement, temperature, humidity, and sea surface temperature**, which are critical inputs for numerical weather prediction models. This results in more accurate forecasts, particularly for severe weather events.

4. Support for Disaster Management

The satellite provides near-instant data on developing **cyclones, floods, forest fires, and volcanic ash clouds**, allowing authorities to take quick preventive measures. Its real-time monitoring capability is instrumental in **early warning systems**, reducing the impact of natural disasters and saving lives.

5. Wide Area Coverage

Positioned at **140.7° East longitude** in a **geostationary orbit**, Himawari-9 continuously observes a large part of the Earth — including **East Asia, Southeast Asia, Australia, and the western Pacific Ocean**. This extensive coverage ensures that a vast portion of the planet receives consistent meteorological surveillance.

7.2 Disadvantages

1. High Development and Operational Cost
One of the major disadvantages of Himawari-9 is its high cost of development, launch, and maintenance. Building and deploying a geostationary satellite involves expenses running into hundreds of millions of dollars. Additionally, maintaining ground stations, upgrading communication systems, and processing vast amounts of data require continuous investment. This makes such projects economically challenging for developing countries.

2. Limited Spatial Coverage (Geostationary Constraint)
Being in a geostationary orbit at 140.7° East longitude, Himawari-9 continuously observes only one portion of the Earth — primarily the Asia-Pacific region. It cannot capture the poles or western hemisphere directly. This limits its usefulness for global coverage and requires coordination with other satellites such as GOES (USA) and Meteosat (Europe) to achieve worldwide observation.

3. Data Overload and Processing Challenges
The satellite's high temporal and spatial resolution leads to the generation of enormous volumes of data. Managing, storing, and analyzing this data requires powerful computing infrastructure and specialized software. Many developing nations and small meteorological agencies lack the resources or bandwidth to process such large datasets effectively, reducing accessibility and usability.

4. Dependence on Ground Infrastructure
Himawari-9's efficiency heavily depends on ground-based receiving stations and the HimawariCast broadcast system. Any malfunction, power failure, or communication disruption at these ground facilities can interrupt data transmission and delay the delivery of critical weather information, especially during emergency situations like cyclones or tsunamis.

5. Susceptibility to Space Weather and Technical Failures
Being located in geostationary orbit, Himawari-9 is exposed to space weather events such as solar flares, cosmic radiation, and charged particles, which can affect its sensors and onboard electronics. Technical malfunctions, sensor degradation, or orientation errors may also reduce image quality or cause temporary service interruptions.