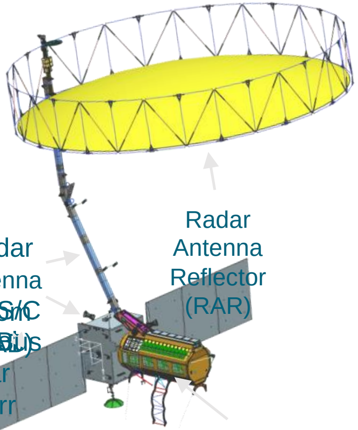
Digital Twin Use cases for Space

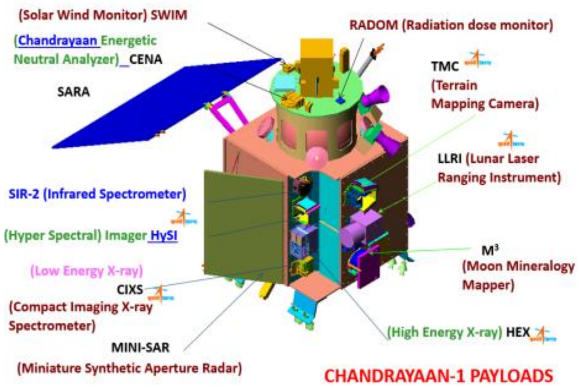
Jai Singla, ISRO
Agenda Item 7.6
WGISS-61 and WGDisaster-25
16-20 March, 2026
Dehradun, India

Committee on Earth Observation Satellites

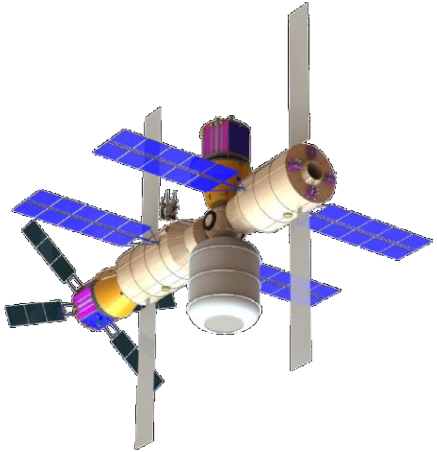
Digital twin opertunities in Space



NISAR



Chandrayaan-1



BAS

Key Technologies:

- Internet of Things based Sensors
- 5G/6G Networks and LORA tech
- Visualization SW support
- High performance computing
- Edge devices
- AI , Machine Learning

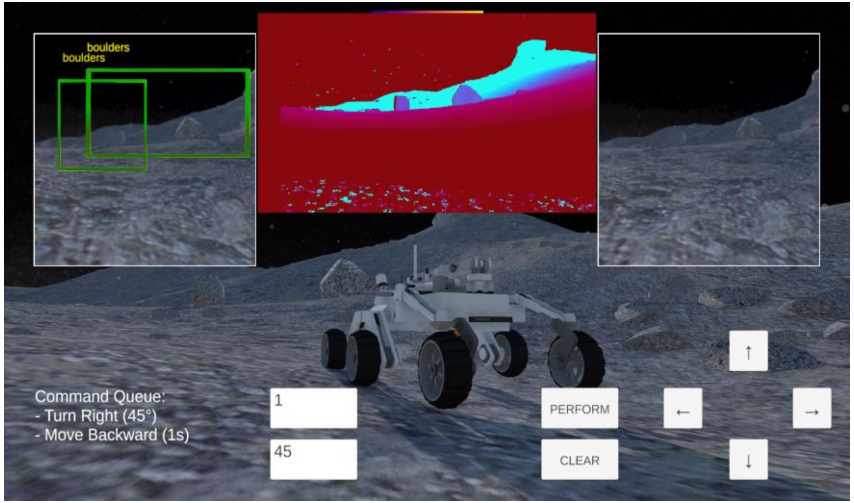
Key Capabilities:

- Real-time monitoring
- Simulation and predictions
- Failure detection
- Optimization
- Intelligent decision-making

Astronauts Health

Futuristic Launch vehicles

EVOLUTION OF DIGITAL TWIN

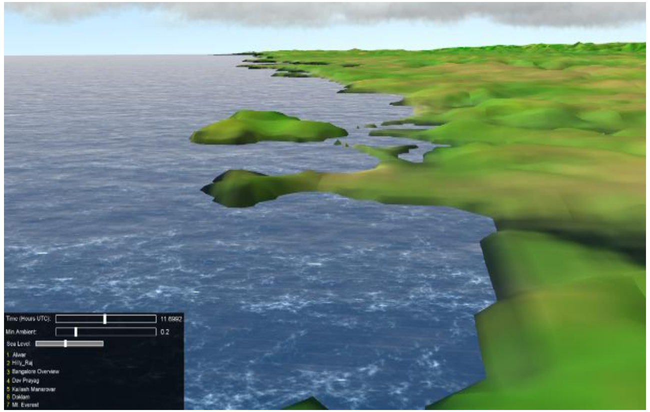


SW Simulation of rover navigation over Moon- Singla, InGARSS 2025

- The Digital Twin concept originated from NASA in the 1960s during space missions. NASA created physical replicas of spacecraft systems on Earth to simulate, monitor, and troubleshoot issues remotely.
- The Apollo 13 mission is a famous example where simulation models helped engineers resolve spacecraft problems.
- In 2010, John Vickers, principal technologist and associate director of the Materials and Processes Laboratory at NASA's Marshall Space Flight Center, coined the term "digital twins," in 2010.
- Connected Digital Model representation at ISRO.

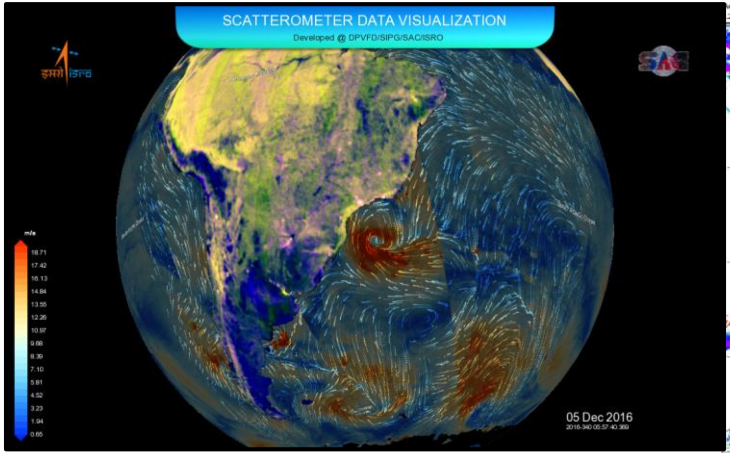
EVOLUTION PHASES

- **1960–2000:** Static simulation models
- **2000–2010:** Connected digital models
- **2010–2020:** IoT-enabled digital twins
- **2020–Present:** AI-driven predictive digital twins

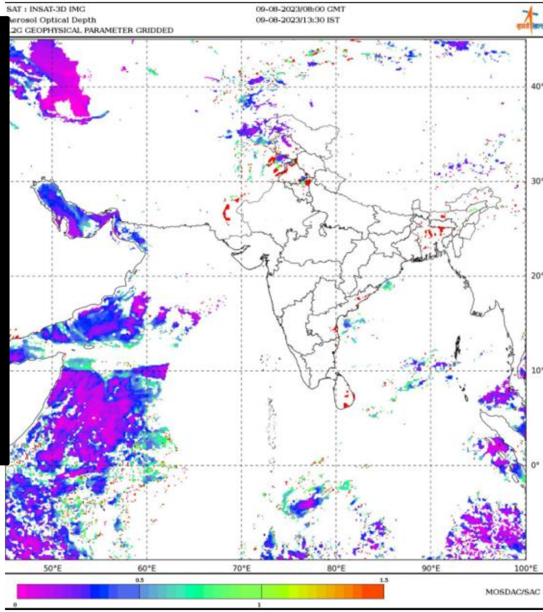


Simulation of sea waves

Singla, ISRS 2020



Scatterometer Data Visualization

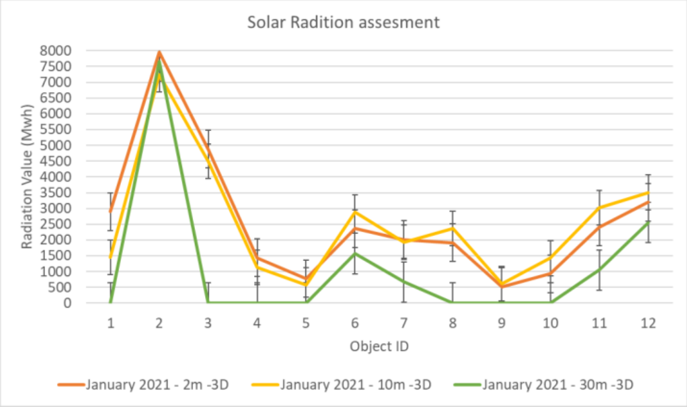


OceanSAT AOD

- Satellite Observations at coarser level. For example for AOD:
  - **INSAT 10km x 10km – 1 pixel**.
  - **Ocean SAT AOD at 1KM x 1KM**
  - ESA **TROPOMI sensor data (5KM x 5KM – 1 pixel)- NO2 pollution.**
- **Observation time from 15 min- 1 hour .**
- Relying on Model forecasting **(Predictions are based on static / historic data)**

Popular practices in monitoring of urban cities using remote sensing data

- Change detection
- Solar power estimation
- Population estimation
- Resources estimation
- Visibility analysis
- Disaster management
- and Strategic planning



Land surface temp. night times (2003-2018)

Singla, JISRS 2023

Popular practices in System Engineering

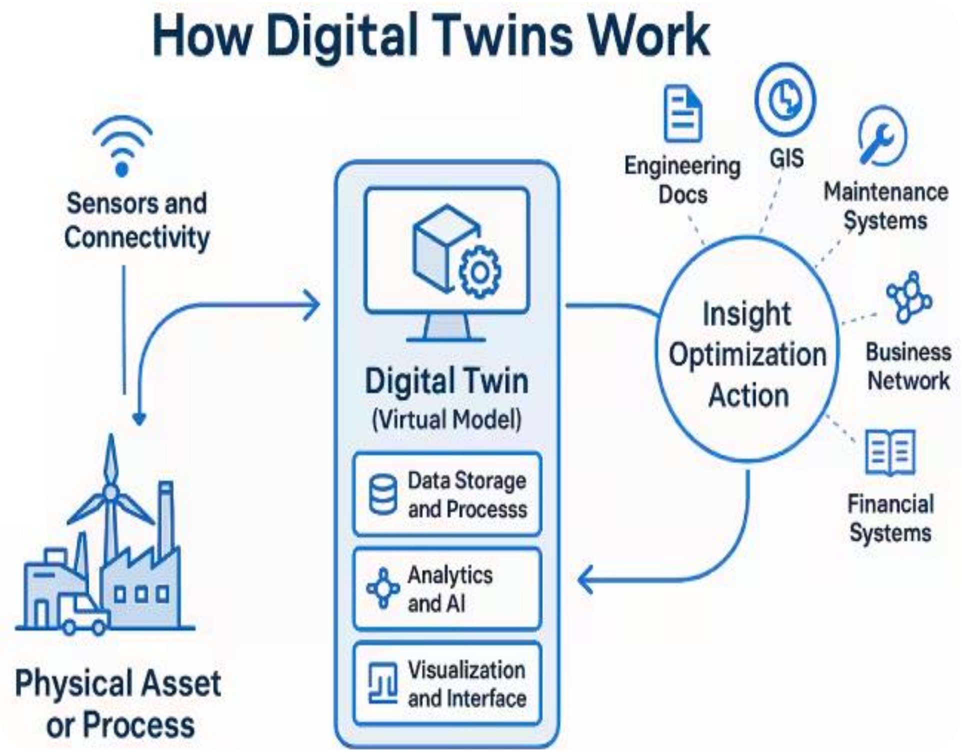
CHAMBER-A THERMOCOUPLE & VACUUM READINGS

CHAMBER VACUUM 1.24395E-06 mbar

THERMOCOUPLE	Value °C	THERMOCOUPLE	Value °C	THERMOCOUPLE	Value °C	THERMOCOUPLE	Value °C
TC-1	2.9	TC-55	6.4	TC-109	5.2	TC-163	3276.7
TC-2	4.1	TC-56	4.0	TC-110	4.7	TC-164	3276.7
TC-3	1.3	TC-57	14.7	TC-111	4.4	TC-165	3276.7
TC-4	3.9	TC-58	7.2	TC-112	4.7	TC-166	3276.7
TC-5	2.5	TC-59	6.7	TC-113	3.1	TC-167	3276.7
TC-6	0.9	TC-60	6.3	TC-114	3.0	TC-168	3276.7
TC-7	2.4	TC-61	26.4	TC-115	3.0	TC-169	3276.7
TC-8	5.8	TC-62	25.7	TC-116	3.0	TC-170	3276.7
TC-9	3.1	TC-63	27.5	TC-117	3.0	TC-171	3276.7
TC-10	1.1	TC-64	26.8	TC-118	2.2	TC-172	3276.7
TC-11	3.0	TC-65	27.8	TC-119	2.6	TC-173	3276.7
TC-12	1.3	TC-66	28.2	TC-120	2.2	TC-174	3276.7
TC-13	2.6	TC-67	25.0	TC-121	3.2	TC-175	3276.7
TC-14	1.5	TC-68	24.9	TC-122	2.7	TC-176	3276.7
TC-15	2.2	TC-69	24.9	TC-123	3.0	TC-177	3276.7
TC-16	0.6	TC-70	25.2	TC-124	1.1	TC-178	3276.7
TC-17	11.2	TC-71	25.0	TC-125	2.5	TC-179	3276.7
TC-18	2.1	TC-72	24.8	TC-126	2.3	TC-180	3276.7
TC-19	1.4	TC-73	23.2	TC-127	2.4	TC-181	3276.7
TC-20	1.7	TC-74	28.1	TC-128	2.4	TC-182	3276.7
TC-21	1.6	TC-75	28.0	TC-129	5.3	TC-183	3276.7
TC-22	1.4	TC-76	25.0	TC-130	4.9	TC-184	3276.7
TC-23	0.8	TC-77	24.9	TC-131	4.4	TC-185	3276.7
TC-24	1.5	TC-78	25.1	TC-132	2.2	TC-186	3276.7
TC-25	3276.7	TC-79	28.4	TC-133	4.8	TC-187	3276.7
TC-26	3276.7	TC-80	28.2	TC-134	4.8	TC-188	3276.7
TC-27	-189.5	TC-81	30.0	TC-135	4.8	TC-189	3276.7
TC-28	-184.8	TC-82	29.7	TC-136	5.0	TC-190	3276.7

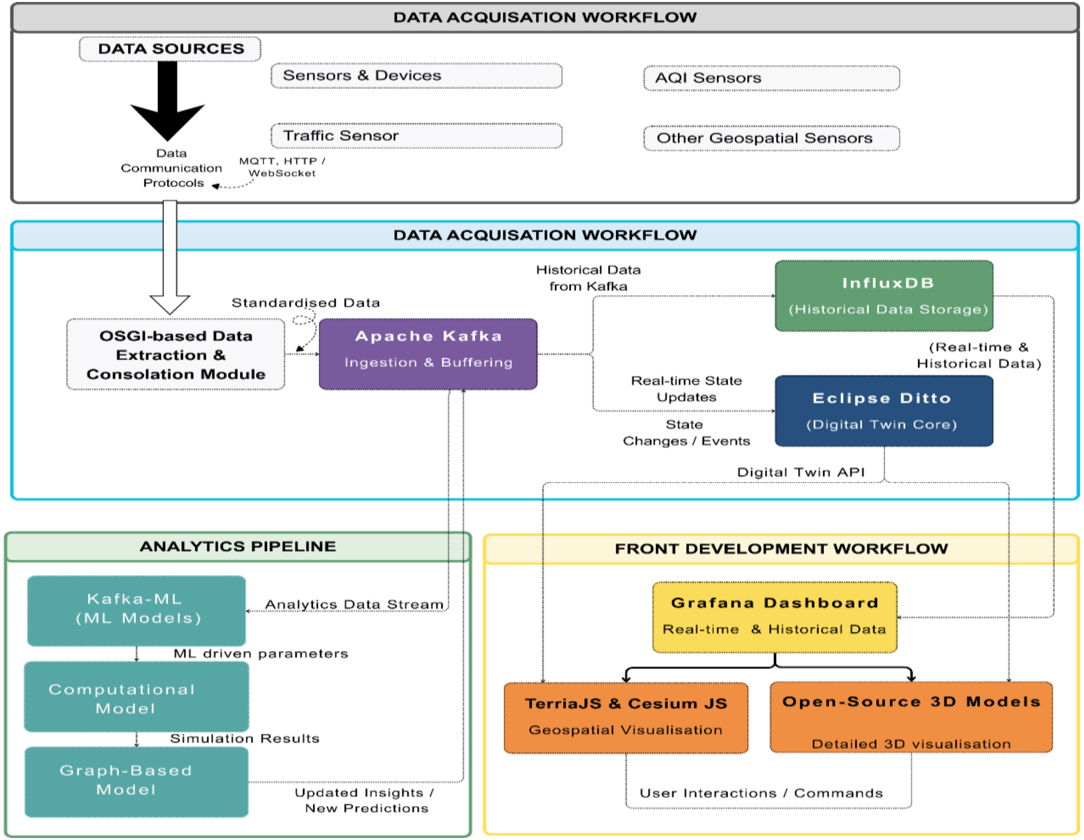
Information of various sensors available through web-interface

Digital Twin Eco-System

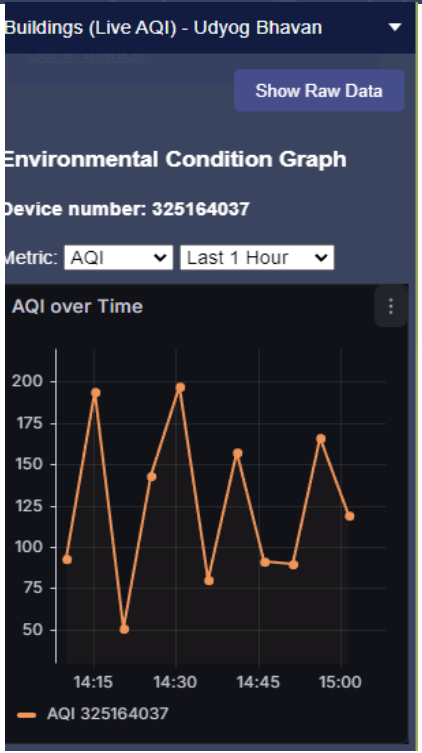


Physical Entity:
Contains sensors, IoT devices, and machines that generate real-world data.
Data Ingestion Layer:
Handles real-time data ingestion using platforms like Apache Kafka.
Data Storage Layer:
Stores time-series and historical data using databases such as InfluxDB.
Digital Twin Core Layer:
Maintains the digital twin state and synchronizes physical and virtual systems.
Analytics and Simulation Layer:
Runs machine learning models and simulations.
Visualization Layer:
Provides dashboards and interactive visualization.
Application Layer:
Provides APIs and applications for monitoring and control.

SW Architecture of Digital Twin



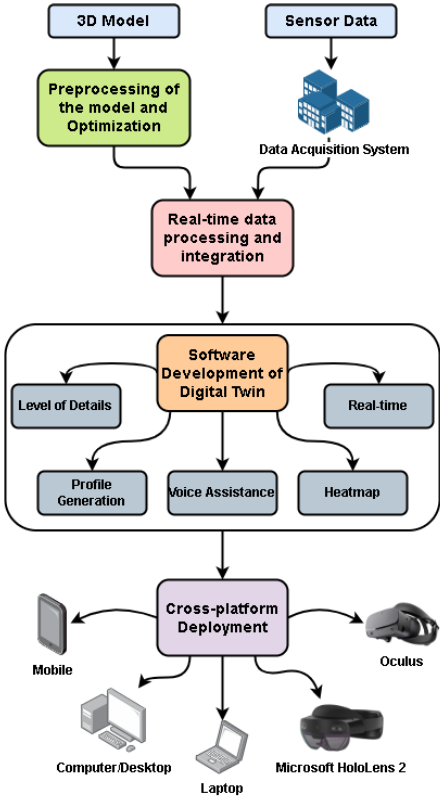
SW Framework for Digital Twin at SAC

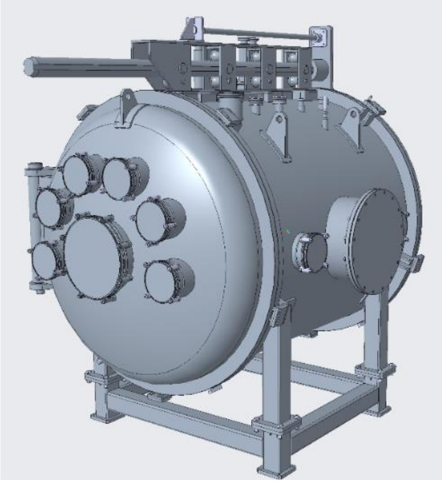


Digital twin framework will cater to input GIS/ Sensor / BIM data and provides ready to use dashboards for the decision makers.

Singla, Curr. Sci 2022

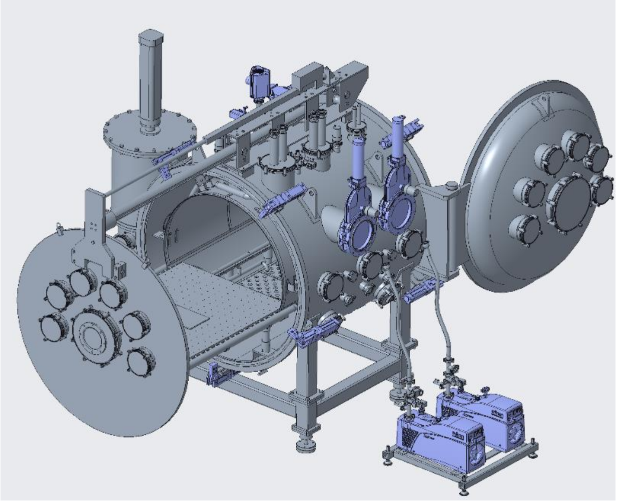
A use case of Digital twin in Engineering





Optimized model

Digital twin of thermal chamber with IoT



Singla, Current Sci. 2023

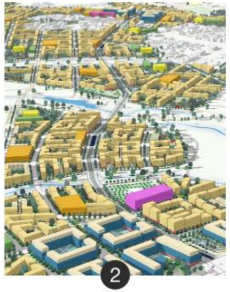
Digital Twin for urban cities

Descriptive Analysis

Visualize the city in 3D and its changes over time such as new assets, roads & bridges, movement of people, demographic & economic changes

- 3D model of all assets
- Street view and building facade
- Socio-economic information
- Demographic details

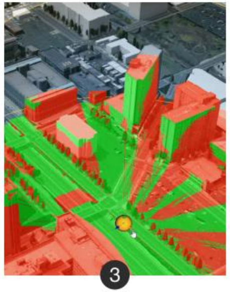
Predictive Modelling



Model, predict and forecast underlying activities in sectors, such as real estate, transport, sustainability & socio-economic sectors

- Understand the relation between changes in demographics, immigration, etc
- Real estate, transport sector and public assets demand predictive analysis

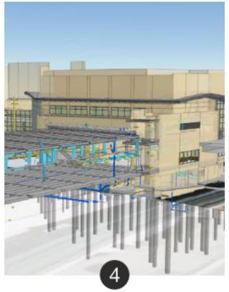
Scenario Planning & Simulations



Run multiple what-if scenarios and simulations by pulling levers of change and its effects on the city

- Model infrastructures to accommodate for changes in the city
- Simulate economic activity & demographic changes

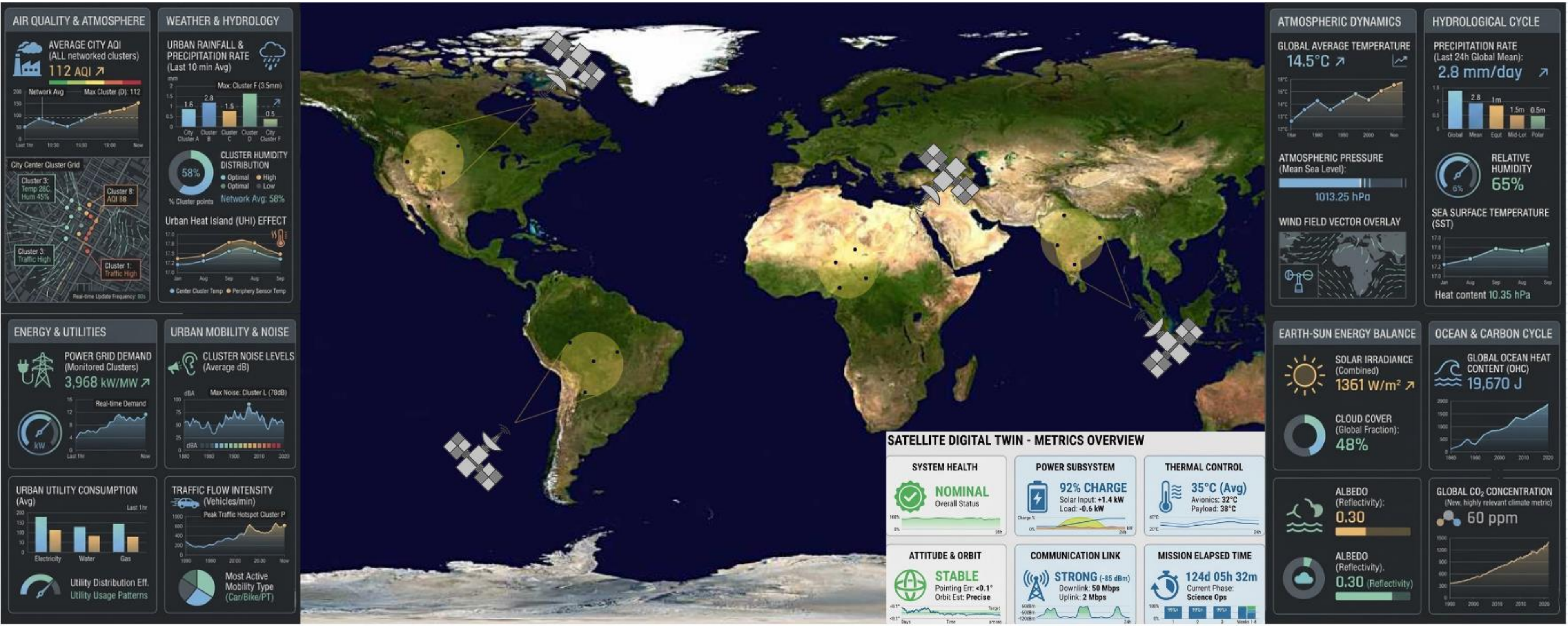
Operational Excellence



Improve operations by making the organization proactive through live command centres and AI powered recommendations backed by real-time data integration

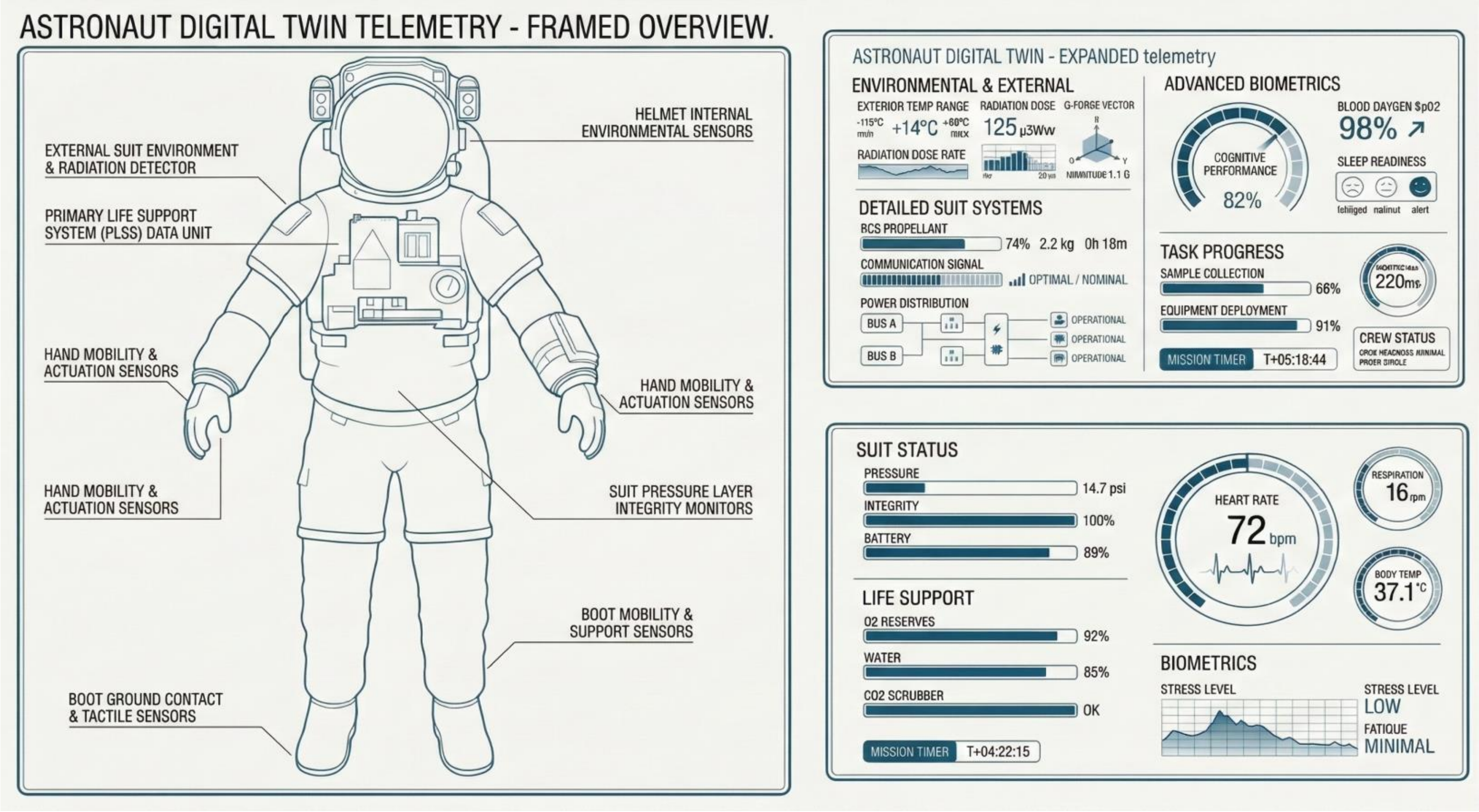
- Live command centre and dashboard powered by AI
- Real-time social listening & impact on real estate and asset management

A use case of Digital twin for Planet Earth

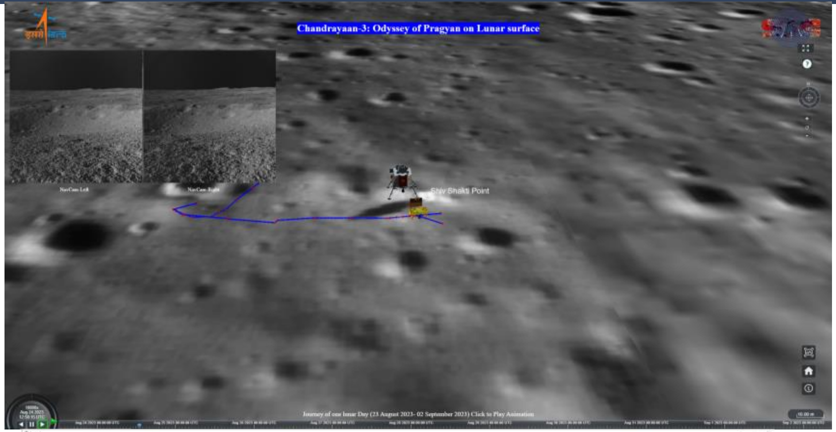


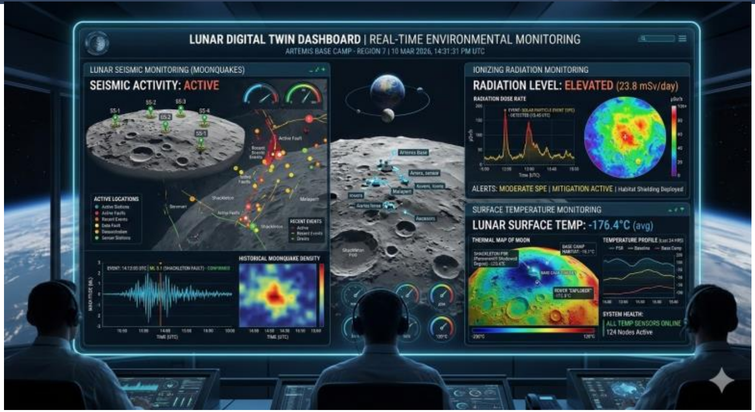
Envisaged Digital twin of Earth Utilizing IOT Sensors and satellite data

Use case of DIGITAL TWIN of an ASTRONAUT

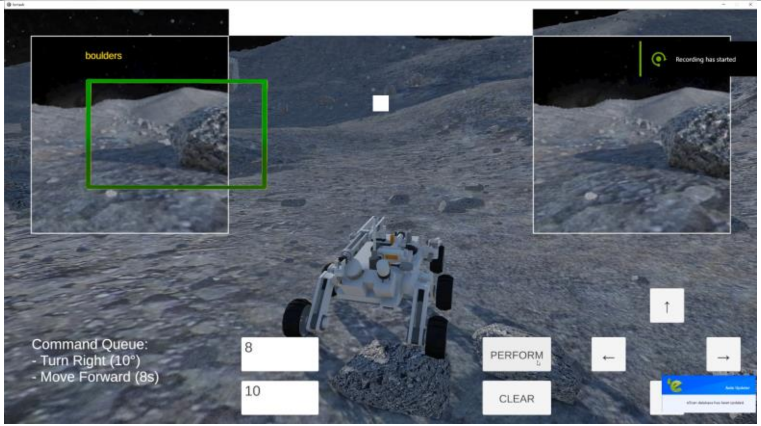


FUTURE – Envisioned DIGITAL TWIN of Moon

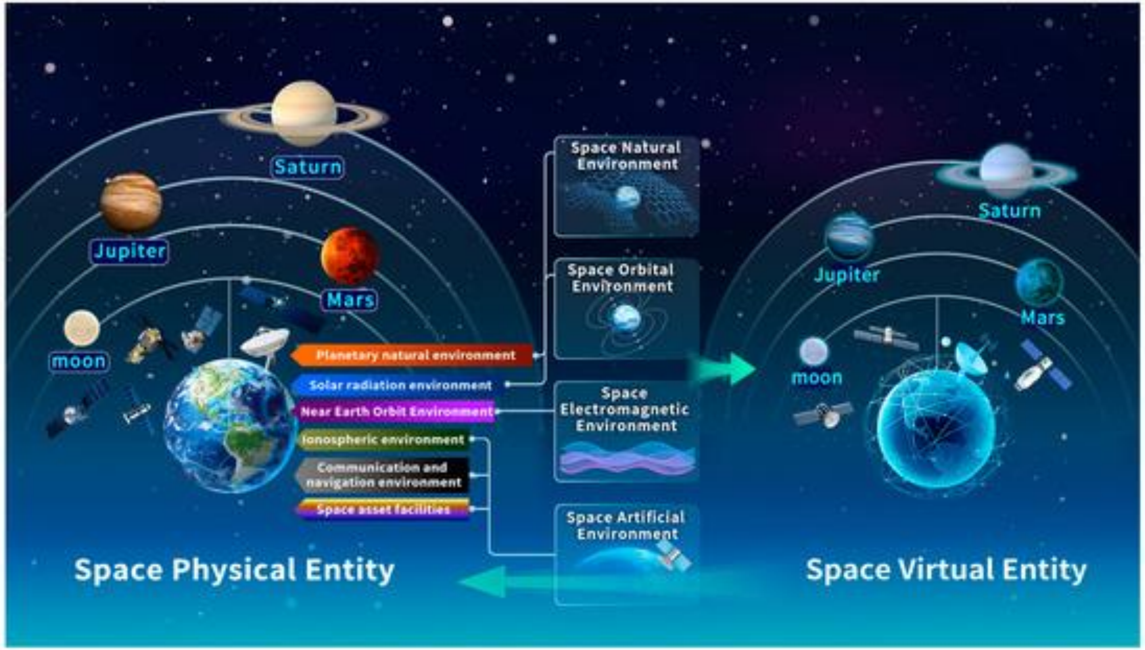


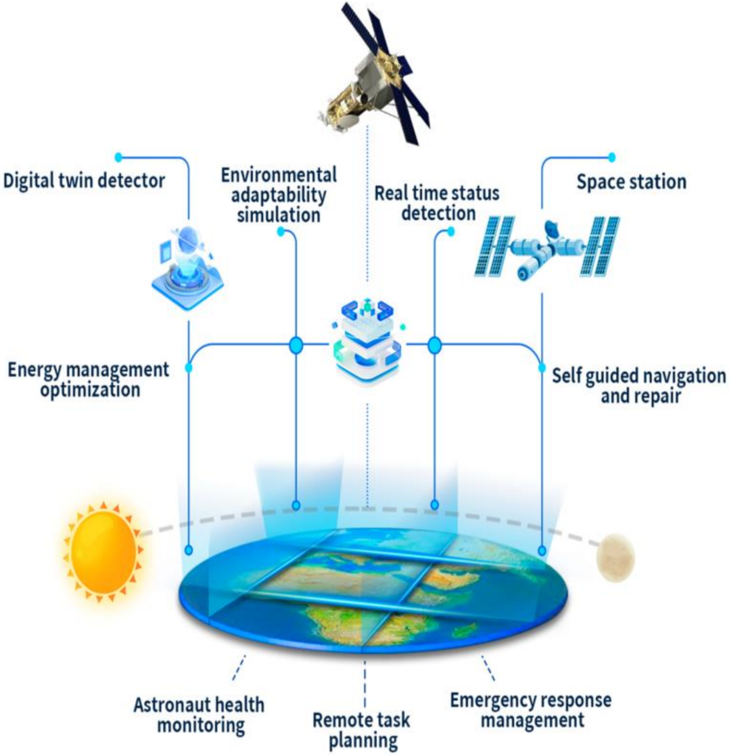


Envisioned Digital twin Of Moon and Lunar rover operations.

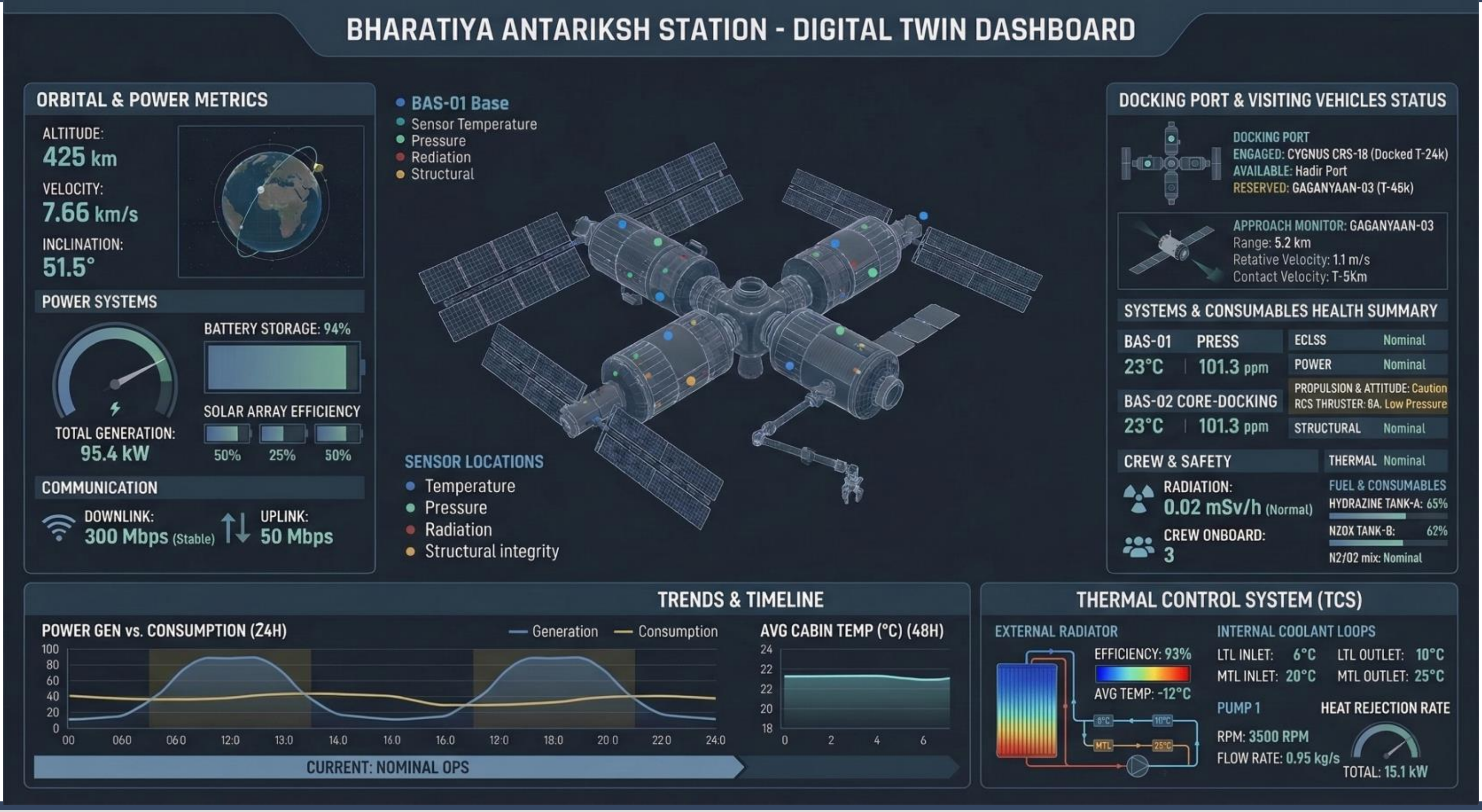


FUTURE – Envisioned Planetary Twin

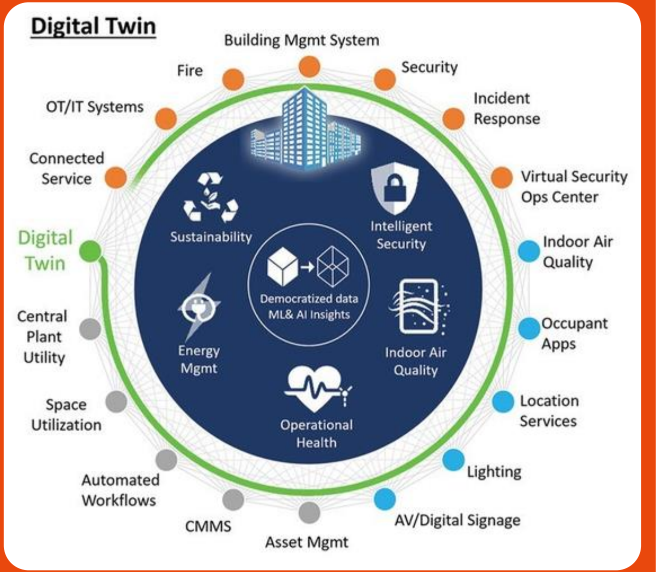




FUTURE – Envisioned DIGITAL TWIN of BAS



CHALLENGES AND LIMITATIONS



LIMITATIONS

Challenges and limitations of Digital Twin:

- High implementation cost
- Integration complexity
- Data security risks
- Scalability challenges
- Model accuracy requirements

Requires:

- High-quality data
- Reliable infrastructure

DISADVANTAGES

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Thanks

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